BEN-GURION UNIVERSITY OF THE NEGEV
FACULTY OF ENGINEERING SCIENCES
DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT

Robotic System for Physical Training of Older Adults

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE M.Sc. DEGREE

By: Omri Avioz-Sarig

Supervised by: Professor Yael Edan

December 2019

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Chairman of Graduate Studies Committee: ……………………….. Date: 18/12/19 ……………

December 2019

Abstract

The world's elderly population is rapidly growing and so is life expectancy. Most older adults prefer to maintain independent living. Physical activity has been proven to offer a better quality of life with several physical and psycho-social health benefits, helping to maintain a satisfactory cognitive, mental and physical state for older adults. It delays function decline and minimizes the rate of mortality, depression, and disabilities.

In this research, a robotic system is developed as a personal coach for older adults. The system aims to motivate older adults to participate in physical activities. The robot instructs the participants and demonstrates the exercises. It also provides real-time corrective and positive feedback according to the performance of the participants as monitored by an RGB-D Kinect camera. Two robotic systems were developed and implemented using the Python programming language.

Experimental studies, composed of a preliminary experiment followed by an experiment with two different humanoid robots (Nao and Poppy), aimed to determine the best timing and mode of feedback that would accommodate user preferences, motivate the users and improve their interaction with the system. A comparative study was also carried out to explore user preferences while training with the two forms of humanoid robots and to determine which of the robots gives better satisfaction.

A preliminary experiment was conducted with ten older adults, aged 67-85, in a home-like environment to keep the interaction as natural as possible. A simulated form of the Nao robot was used, due to a failure in the real robot. Yet, the results revealed that 70% of the participants expressed their intention to use the system in the future.

This gave the motivation for a follow-up study with thirty-two older participants, aged 70-88. The experiment was a between-within design where the independent variables were the timing and mode of feedback and the type of humanoid robot. Each older adult interacts with Nao and Poppy robots at different sessions in a randomized order as the feedback preferences are being assessed. The dependents variables are perceived usefulness, ease of use, attitude and behavioral intention to use which were assessed both objectively and subjectively. The study reveals the potential of a robotic system to provide older adults with the independence and motivation to participate more effectively in physical activities which is beneficial to their health and general wellbeing. The research provides specific design guidelines with special focus on feedback design.

The results revealed that the system fulfills the aim of motivating older adults to engage more in physical exercises. Most of the users perceived the system as very useful and easy to use. Users had a positive attitude towards the system and noted their intention to use it. Continuous feedback significantly increased positive attitude, engagement and ease of use of the system. The results also revealed that the Poppy robot engaged the users more than the Nao robot. This is probably due to the more technical features of the Poppy robot versus the more toy-like Nao robot. Audio and visual feedback is the preferred mode of feedback with regards to ease of use of the system and the engagement.

The specific thesis contributions are the development of a physical robotic system, and the evaluation of feedback and type of robot in HRI for older adults. Specifically, the research focused on which forms of feedback should be given, how should the feedback be given and when should the feedback be given to improve the experience that the older adults have while interacting with the robot during the exercise sessions.

Key Words: Older Adults, Physical Activity, Feedback, HRI, Humanoid Robot, Kinect, NAO, Poppy

This work has been presented at the following conferences:

- Avioz-Sarig O., Olatunji S., Sarne-Fleischmann V., Edan Y. 2019. Robotic system for physical training of older adults, Robotics: Science and Systems, RSS 2019 - June 23, 2019 – Freiburg, Germany. Extended abstract, poster presentation.

- Avioz-Sarig O., Olatunji S., Sarne-Fleischmann V., Edan Y. 2019. Robotic system for physical training of older adults, ICR 2019 – 6th Israeli Conference of Robotics, July 2019, Herzelia, Israel. Abstract, oral presentation.

A journal publication has been submitted:

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Avioz-Sarig O. 2019. Robotic system for physical training of older adults. Final Project. Department of Industrial Engineering and Management, BGU.

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1 Introduction

1.1 Problem description

The aging population rate is rising rapidly (United Nations, 2017) while the number of caregivers and nurses is deteriorating (Buerhaus, 2008). The high cost of long-term care for older adults is an issue that cannot be ignored and it increases the financial burden on public health service and family members (Aurilla & Arntzen, 2011).

There are several solutions to provide long-time care for older adults using technological aids such as smart homes (Demongeot et al., 2002), virtual caregivers (Albaina, Visser, Van Der Mast, & Vastenburg, 2009), wearable safety monitoring sensors (Patel, Park, Bonato, Chan, & Rodgers, 2012; Primer & Guide, 2016) and robots. Some of the eldercare robot applications include providing physical support to the older adults, social interaction, cognitive stimulation and safety monitoring ***(Table 1)***. It is important that the robots should augment the quality of life for the older adults yet not take away what they enjoy about life (Lewis, Metzler, & Cook, 2016a).

The decline of physical and mental capability with age is unavoidable (McMurdo & Rennie, 1993; Salguero, Martínez-García, Molinero, & Márquez, 2011). Inactivity of older adults often results in functional decline, loss of independence and increased disease burden (Phillips, Schneider, & Mercer, 2004). Exercises can delay, prevent, or even reverse these effects (Phillips et al., 2004). However, older adults do not engage in exercises as much as is recommended for their health (Phillips et al., 2004).

Several technologies have been developed to encourage physical activities (***Table 3***) such as exer-games for mobility, virtual reality simulator, smartphone applications, embodied conversational agents and Wii Fit. Some studies used video-based games and dance to motivate the older adults for exercise (Brox et al., 2016) while some other studies compared the effectiveness of physical robot coaches and virtually embodied coaches (Fasola & Mataric, 2013).

Robot coaches have also been used to encourage children exercising. The robot coach was effective in terms of companionship and social interaction (Guneysu & Arnrich, 2017). It has been shown that a robot coach could be as effective as a human coach (Ramgoolam, Russell, & Williams, 2014).

Positive feedback during exercise sessions has a significant beneficial effect on the experience of older adults (Fasola & Mataric, 2013; Lewis, Metzler, & Cook, 2016b). The timing (Mirnig, Riegler, Weiss, & Tscheligi, 2011) and mode of feedback have an influence on the interaction with the system and its effectiveness (Baraka & Veloso, 2018; Rosati, Rodà, Avanzini, & Masiero, 2013). However, the specific mode of feedback and form of timing must be identified in order to ensure continuous motivation for the older adults during the physical exercise session.

1.2 Objectives

In this thesis, we developed a robotic system for physical training of older adults. The research presents the system design and its implementation and focuses on how to utilize appropriate mode and timing of feedback to generate a pleasurable, encouraging and stimulating experience for the older adults during their exercise sessions. Preferences of the older adults regarding the type of robot are also explored to further improve the interaction. The specific objectives are to:

1. Develop a physical training system for older adults.
2. Explore the most suitable timing of feedback that will motivate the older users.
3. Identify the mode of feedback that will improve social interaction with the system.
4. Compare training experience with two different humanoid robots.

2 Literature review

The scientific background related to the different parts of the research is reviewed in this section including older adults (2.1), physical activity (2.2), technologies for enhancing physical activity (2.3), and finally a review of feedback in HRI (2.4).

2.1 Older adults

The common definitions for the terms ‘elderly’, ‘old age’ are often associated with decline and deterioration in health, vitality, social usefulness and independence (Victor, 1994).

The population that is 60 years and above, rapidly grows in most of the countries at an average of about 3% per year (United Nations, 2017). In 2017 there are 962 million elders, and the predictions are for 1.4 billion in 2030, 2.1 billion in 2050 (22% of the world’s population (Rezende, Matsudo, & Luiz, 2014)) and 3.1 billion in 2100 (United Nations, 2017). Furthermore, in 2050, the population above 80 years old will be three times more than today (United Nations, 2017). Life expectancy worldwide grew from 65.3 in 1990 to 71.5 in 2013 (Abubakar, Tillmann, & Banerjee, 2015). On the other hand, there is a decline in fertility rates (Sakamoto, Fern, Han, & Tong, 2016) and as a result, the rate of nurses and caregivers is already in shortfall (Fasola & Matarić, 2012).

The main reasons that this population has grown consistently over the last decades is due to the progress in medicine and treatment, better understanding of healthy lifestyles such as physical exercise, mental exercise, food intake, supportive environment, and better social security for the older adults (Lewis et al., 2016a).

People above 65 years old are considered older adults (Czaja, Boot, Charness, & Rogers, 2019). However, there is a significant distinction between “younger-old” adults, (65-74 years), “old-old” adults (75-84 years) and “oldest old” (85+ years) (Czaja et al., 2019; Parry & McCarthy, 2017). It is reflected in their lifestyle, health level and participation in the number of activities (Eisma et al., 2003).

As people get older, their body changes and cognitive abilities may deteriorate (Murman, 2015). Cognition is divided into two roles, maintaining communication with other people and maintaining independence (e.g., taking medications alone, driving safely, managing the household). The cognitive speed could drop by approximately 40–60% at age 80, and memory could decline at older ages (Christensen, 2001). The physical and sensory function may also deteriorate (Murman, 2015). There could be a loss of muscle mass, loss of strength, and physical performance which leads to increased fear of falling, and decline of muscle mass and physical performance which deteriorates the quality of life (Trombetti et al., 2016). It is estimated that 25-50% of people older than 85 years are estimated to be frail. These people have a substantially increased risk of falls, disability, long-term care, and death (Clegg, Young, Iliffe, Rikkert, & Rockwood, 2013).

Older adults desire to choose where and how they age in place (Wiles, Leibing, Guberman, Reeve, & Allen, 2012) and they want to live independently as long as possible (Bedaf, Gelderblom, & De Witte, 2015). They prefer not to be institutionalized in sheltered homes, or nursery homes even if they suffer from health and age-related problems (Broekens, Heerink, & Rosendal, 2009). It was discovered that people who live in the same place as they grow old, have a greater sense of security and familiarity both in their homes and in their communities (Wiles et al., 2012). They feel more independent and important since they have long-lasting relationships in their communities (Wiles et al., 2012). However, to fulfill this, the older adult should be suitable physically and cognitively able (Wiles et al., 2012). Unfortunately, some age-related physical and mental complications are common (McMurdo & Rennie, 1993; Salguero et al., 2011). Research has shown that being physically active can delay and reduce this phenomenon (WHO, 2010).

2.1.1 Motivation factors for the older adults

Technology has the potential to provide support for the rapidly growing older adult population, even though, it has been slowly adopted by this population (Mitzner et al., 2016). The common perspective is that seniors do not adopt innovative technologies because they do not have experience with it and they are anxious about it (Czaja et al., 2006). Two main reasons influence the older adults low motivation: lack of commitment and the degree of investment they need to succeed in using technology (Leonardi, Mennecozzi, Not, Pianesi, & Zancanaro, 2008).

“To be motivated means to be moved to do something“ (Ryan & Deci, 2000). Motivation can be divided into intrinsic and extrinsic motivation (Legault, 2016). Intrinsic motivation refers to behavior that is driven by internal rewards (Legault, 2016) and results in excellent learning and creativity (Ryan & Deci, 2000). An example of intrinsic motivation in this context of a robotic coach is a robot that never gives negative feedback in order to avoid diminishing intrinsic motivation to engage in the exercise task (Fasola & Mataric, 2013). In contrast, extrinsic motivation involves engaging in a behavior in order to earn external rewards or avoid punishment

(Legault, 2016; Ryan & Deci, 2000). Example of extrinsic motivation in the context of a robotic coach can help short-term processes (Fasola & Matarić, 2012) while intrinsic motivation can help long-term processes (Vallerand & Reid, 1984).

Important factors that influence the intrinsic motivation level of older people are (Pyae, Luimula, & Smed, 2016):

i. Social functioning (Krause, Frank, Dasinger, Sullivan, & Sinclair, 2001; Maclean, Pound, Wolfe, & Rudd, 2002; Santus, Ranzenigo, Caregnato, & Inzoli, 1990; Shimoda & Robinson, 1998) as found in networked games, multiplayer games, and inter-generational games (Pyae et al., 2016). For example, in the study of Aarhus at el. the older adults were motivated by the fact that their grandchildren play Nintendo Wii with them (Aarhus, Grönvall, Larsen, & Wollsen, 2011).
ii. The relationship between the caregivers or the therapist and the older adults (Barry, 1965; Maclean et al., 2002).
iii. The seniors having personal goals. For example, "How will achieving the goal change their life" (Phillips et al., 2004).

Other motivational factors for older adults are information from healthcare professional (White et al., 2012), positive feedback, positive reinforcements, encouragement from caregivers (Brox et al., 2016; Van Vliet & Wulf, 2006) music (Knight & Wiese, 2011) and competition (that can be demotivating too) (Aarhus et al., 2011).

2.1.2 Robot applications for older adults

In the last two decades, there has been a rise in the development of social robots (Broadbent, 2017) but still the research on older adults' interaction with robots is in its infancy (Zafrani & Nimrod, 2019). Robots have been developed for several applications to help people at their homes, schools, shopping malls, hospitals and so on (Broadbent, 2017). Daily living activities of older adults have been classified into activities of daily living (ADLs), instrumental activities of daily living (IADLs) and enhanced activities of daily living (EADLs) (Smarr et al., 2012). ADLs involve self-maintenance activities such as feeding, bathing, and eating while IADLs involves activities where the older adults get to relate with the external environment such as shopping, transportation use, etc. (Lawton, 1990). EADLs are activities that engage the older adult in social and enriching activities (Rogers, Meyer, Walker, & Fisk, 1998). Physical activities and exercise sessions fall under the EADL category and have been revealed to be very relevant to healthy aging (Fasola & Mataric, 2013).

2.1 Physical activity

Physical activity is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" (Caspersen & Christenson, 1985). It is proven that the fourth leading risk factor for global mortality, accounting for 6% of deaths globally, is physical inactivity (United Nations, 2017). In addition, it is estimated to be the main cause for approximately 21% - 25% of breast and colon cancers, approximately 30% of ischemic heart disease burden and 27% of diabetes (United Nations, 2017).

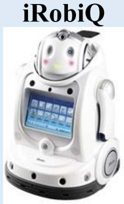
The worldwide cost of physical inactivity through health-care systems and productivity losses was $67.5 billion in 2013, of which $31.2 billion was paid by the public sector, $12.9 billion by the private sector, $9.7 billion by households and $13.7 billion were responsible for productivity losses related deaths (Ding et al., 2016).

It is also proven that physical activity provides health benefits for older adults and is directly correlated to a reduction in mortality, morbidity, and disability (Czaja et al., 2019; Gorman et al., 2014; Healy, Winkler, Owen, Anuradha, & Dunstan, 2015; Landi et al., 2007; Nied & Franklin, 2002). It assists in improving cognitive function (Northey, Cherbuin, Pumpa, Smee, & Rattray, 2018) and maintaining good physical and psychological health and well-being. It also helps in reaching or maintaining a healthy weight, preserving physical function, mobility and independence, maintaining social contacts and remaining engaged with the local community, engaging in opportunities involving learning new skills and experiences, maintaining higher levels of energy and vitality, improvements in quality and quantity of sleep and lower levels of anxiety and depression, improved mood and self-esteem (British Heart Foundation National Centre, 2015; Crespo, Idrovo, Rodrigues, & Pereira, 2016). According to UK Medical Officers' guideline, regular exercises reduce chances of type 2 diabetes by 40%, cardiovascular disease by 35%, falls, dementia, and depression by over 30%, joint and back pain by 25% and colon and breast cancer by 20% (Reid & Foster, 2017).

Table 1 presents robot applications for older people in three categories: pet robots, mechanoid robots, and humanoid robots. The table includes assistive robots as well as mental, healthcare and social companionship robots.

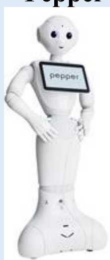
Table 1: Robot applications for older adults

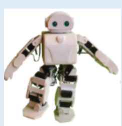
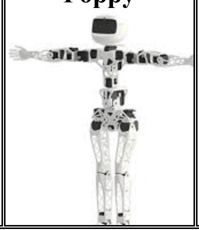
Type	Technology	Description & Purpose	Category	Interaction Modality	Feedback from robot	Activity Monitoring	Reference
Pets	**Paro** 	A therapy seal robot for seniors. It has a white surface in the form of fur. There are tactile sensors on the robot's body and the fur creates a natural feeling when the user touches the robot.	Social Robot; Therapy; Robotics EADL	Facial expressions, sight, gestures, speech and tactile sense.	Provides gestures and facial expressions. This depends on the person and the environment.	Tactile detection using tactile sensors.	(Wada & Shibata, 2007)
	AIBO 	A robotic dog used in therapy sessions for seniors feeling lonely in a long-term care facility. It can hear, see, and perceive commands. It also learns, expresses emotions and can adapt to its environment.	Social Robot; Therapy Robot EADL	It has an illuminated face to communicate detection of impulses.	-	-	(Banks, Willoughby, & Banks, 2008; Bemelmans, Gelderblom, Jonker, & De Witte, 2012)
	NeCoRo 	It is a cat-like communication and mental health robot with artificial intelligence. It also has multiple built-in sensors to provoke playful communication. It evokes highly emotional responses from humans by mimicking a real cat's reactions.	Social Robot; Mental Health Robot EADL	Gestures	It stretches his body, opens and closes its eyes, moves its tail, meows, and cuddles when being touched.	Tactile detection using tactile sensors.	(Libin & Libin, 2003)
	iCat 	It has mechanically facial expressions and works as a desktop user-interface robot. it can recognize faces and objects including speech and sound. It is used in research and commercially available.	Social Robot EADL	Facial expressions and speech.	Lights and music.	-	(A. van Breemen, Yan, & Meerbeek, 2005)

	Nabaztag 	Personalized health conversational robot	Healthcare Robot EADL	Voice recognition and speech.	Broadcasts voice messages.	Voice recognition using microphones.	(Klamer & Allouch, 2010)
Mechanoid	**Cafero** 	A robot companion used to remind people to take their medications and also take some physiological measures. It also provided entertainment and cognitive stimulation.	Healthcare Robot IADL	Touch screen interface, Tray-friendly arms.	Visual and audio feedbacks.	Gives visual and audio reminders, takes blood pressure measurements and pulse oximetry. Can provide entertainment and cognitive stimulation.	(Broadbent, 2017; Broadbent et al., 2015, 2014a)
	Care-O-bot 3 	Mobile robot assistant to actively support older adults at home	Assistive Robot ADL	The robot can be equipped with one arm for interaction. It also has a tray for serving items. If the intended purpose is to serve drinks, one hand can be replaced by a tray, or the mobile base platform can be used on its own as a serving trolley. Touch screen also included.	Provides facial feedback, LED lights.	3D-RGBD camera (range 15-200cm) for navigation, object detection, manipulation and grasping.	(Fraunhofer Institute for Manufacturing Engineering and Automation, 2018)
	Matilda 	Human like assistive and communication robot to engage older adults better	Assistive Robot; Social Robot EADL	Baby like face for expressions, voice for speech, body motions for expressions and dance	Touch sensors, speech recognition, body motion sensors.	Monitors speech of users, emotions and movements to engage the older adults. it is also used to monitor eating habits of the older adults.	(Khosla, Chu, Kachouie, Yamada, & Yamaguchi, 2012)
	iRobiQ 	A robot companion also to provide reminders for older adults	Healthcare Robot IADL, EADL	Facial expression, touch screen.	Visual and audio feedbacks.	Gives reminders, takes some physiological measures measurements and pulse oximetry.	(Broadbent et al., 2014b)

	Robear 	Nursing care robot, healthcare in nursing home	Healthcare Robot ADL	Interacts by lifting a patient from a bed into a wheelchair or providing assistance to patients who require help in standing.	It includes actuator units with a very low gear ratio, allowing the joints to move very quickly and precisely, and allowing back drivability, meaning that the force encountered by the actuators as they perform their tasks can be quickly fed back into the system, allowing softer movement. It also incorporates three types of sensors, including torque sensors and Smart Rubber capacitance-type tactile sensors made entirely of rubber, which allow for gentle movements	It incorporates several features that enable it to exert force gently based on what it senses with its tactile sensors.	(Wiederhold, 2017; Wilkinson, 2015)
	LEA (Lean Empowering Assistant) 	Provide support to older adults and assist them to spend their time safely and actively. It moves autonomously, helping the older adults getting out of chair and bad, encouraging them walking at good posture. LEA can remind user to make his daily activities. It has interactive screen that enable contact of care workers, family and friends.	Assistive Robot ADL, EADL	Speech, text-to-speech, gesture, and a graphical user interface with touch.	Alarms and detects and emergencies events. Reminder functions.	Measures the progress of the user's stance.	("LEA - Robot Care System," 2017)
	Robovie 	A conversational robot designed to engage older people by greeting and chatting with them	Social Robot EADL	Speech recognition and use of gestures to converse with the users during interaction. use of the arms to carry items for the user.	Speech and gestures.	Conversations to engage and simulate the older adults.	(Sabelli, Kanda, & Hagita, 2011)

	HOBBIT 	It monitors the seniors' health status at home and mediate social communication. It additionally assists in fetch and carry tasks. Its purpose is to enable seniors live independently in their homes.	Health Robot; Social Robot ADL, IADL		Written text and text-to-speech.	Gesture recognition to create interaction between the user and the robot.	(Fischinger et al., 2016)
	HealthBot 	It consists of microphones, ultrasonic sensors, rotatable touch screen, laser range finder and bumper sensors. It includes the following service application modules; entertainment, falls detection, vital signs measurement, medication reminding, brain fitness games, telephone calling and brain fitness.	Health care Robot ADL, EADL	Synthesized speech feedback, movements and Visual output on the screen.	-	Falls detection, vital signs measurement and brain fitness.	(Jayawardena et al., 2012)
	Nursebot (Pearl) 	The aim is to assist the nurse in caring for seniors. This robot could provide many services for older adults, like guiding through their environments, alerting, informing them of an upcoming event or appointment, monitoring the person's progress and adjusting the robot's velocity and path accordingly etc.	Health care Robot ADL, IADL, EADL	Speech and touch-sensitive graphical displays.	Guiding through environments, alerting and monitoring the user's progress.	Monitoring and detects people.	(Montemerlo, Pineau, Roy, Thrun, & Verma, 2002)
	***Nao** 	An autonomous, programmable humanoid robot. Has 25 degrees of freedom, equipped with two cameras, an inertial measuring unit, sonar sensors in its chest, and force-sensitive resistors under its feet, more than 50 sensors and wide range of possible interactions.	Assistive Robot; Social Robot EADL	Voice recognition and speech, gestures with arm.	LED lights, talking, play music.	Assists as a robot exercise instructor and communicates the exercise instructions to the group. It also demonstrates the exercises. It gives feedbacks on performance in the exercises and corrects wrongly performed activities	(Gouaillier et al., 2008; Lewis et al., 2016a; Ondras, Celiktutan, Sariyanidi, & Gunes, 2017; C. Park & Kim, 2016)

Humanoids	***Pepper** 	Designed to be companion in our life and to communicate with human. Used at train station or hypermarket to show information.	Assistive Robot IADL, EADL	Voice recognition and speech, touch screen interface.	LED lights, talking, play music, display on the tablet.	Gesture and the motion of the user.	(Gardecki & Podpora, 2017; Hsieh, 2017)
	Bandit 	A human-shaped robot. Designed to be a genuine day-to-day companion, whose number one quality is his ability to perceive emotions. It capable of identifying the principal emotions	Assistive Robot; Social Robot EADL	Speech, gestures.	One DOF expressive eyebrows for facial expressions, and a two DOF expressive mouth for mouth expressions during speech.	The robots instruct with speech and demonstrates with the arms what the participant should do in imitation. It also assesses the memory capacity of the user.	(Fasola & Mataric, 2013)
	***Brian 2.1** 	A socially assistive robot to aid older adults with cognitive stimulation and other self-care activities	Social Robot; Assistive Robot EADL	Voice interaction with gestures	Using gestures, facial expression and voice instructions and encouragements.	It monitors and stimulates the older adults during eating and exercises.	(McColl, Louie, & Nejat, 2013)
	***Elli Q** 	Helps older adults stay active and engaged with a proactive social robot that overcomes the digital divide. Elli Q enables older adults to use a vast array of technologies, including video chats, online games and social media to connect with families and friends and overcome the complexity of the digital world.	Assistive Robot; Social Robot IADL, EADL	Voice recognition and speech, touch screen interface.	Talking, lights	-	("ELLI Q," 2018)

	Kompai 	A mobile robot that help for frail people and caregivers. Provide fall risk detection, health monitoring and help getting up	Assistive Robot; Health care Robot; ADL, IADL	Voice recognition with autonomous navigation. It has a video conferencing system.	Alarms, speech synthesis, display on his tablet.		(“KOMPAI Robots Help Frail People and Caregivers,” 2017)
	Romeo 	Advanced humanoid robot designed to assist older adults and disabled individuals in their daily activities. Enable to open doors, climb stairs and reach objects on a table.	Assistive robot; Health care Robot; Social Robot ADL, IADL, EADL	Voice recognition, gestures with arms, facial expression.	Speech synthesis, gestures		(SoftBank, 2017)
	***Kiro** 	A small humanoid robot (height 20 cm), has 18 DOF that allow the robot to move its arms and legs.	Assistive Robot; Social Robot EADL	Text to speech, gestures	-	-	(Cruz-Sandoval, Penaloza, Favela, & Castro-Coronel, 2018)
	Poppy 	Poppy is an open-source 3D printed humanoid robot. Poppy was designed to be anthropomorphic with 25 degrees of freedom (DOF) including a 5 DOFs articulated trunk. LCD screen can be added to the head. Exist in torso version as well.	Assistive Robot; Social Robot Health care Robot EADL				(Lapeyre *et al.*, 2014; Devanne *et al.*, 2018)

* Robotic applications that have been specifically used for enhancing physical activities with the older adults.

Participating in any amount of exercise provides several health benefits including maintaining physical and cognitive functioning. Some exercises are better than nothing, and more exercise increases health benefits (Department of Health Physical Activity Health Improvement and Protection, 2011). A significant reduction in risk of having breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events was diagnosed in people who exercise regularly more than the minimum recommended (Kyu et al., 2016). There is also risk in physical activity for older adults that can problems such as pains(Park & Shoemaker, 2009). However, the potential benefits far exceed the potential risks associated with physical activity (Tremblay et al., 2011).

Recommendations from (Chodzko-Zajko et al., 2009; Department of Health Physical Activity Health Improvement and Protection, 2011; U.S. Department of Health and Human Services, 2008; WHO, 2010) for older adults (≥ 65 years) are:

- At least two hours and thirty minutes of moderately-intensive aerobic physical activity or at least one hour and fifteen minutes of vigorously-intensive aerobic physical activity or an equivalent combination of moderate and vigorous activity per week. Aerobic activity should be performed in bouts of at least ten minutes duration. Muscle-strengthening activities should be done involving major muscle groups, on two or more days a week. For additional and more extensive health benefits, the older adults should increase their moderate-intensity aerobic physical activity to five hours per week. They can also engage in two hours and thirty minutes of vigorously-intensive aerobic physical activity per week, or an equivalent combination of moderate and vigorous-intensity activity (Chodzko-Zajko et al., 2009; Department of Health Physical Activity Health Improvement and Protection, 2011; U.S. Department of Health and Human Services, 2008; WHO, 2010).
- Older adults of this age group, with poor mobility, should perform physical activity to enhance balance and prevent falls on three or more days per week. When adults of this age group cannot do the recommended amounts of physical activity due to health conditions, they should engage in as much physical activity as their abilities and conditions can allow (Chodzko-Zajko et al., 2009; Department of Health Physical Activity Health Improvement and Protection, 2011; U.S. Department of Health and Human Services, 2008; WHO, 2010).

In 2019, only about 12% of people aged above 65 years old participate in the recommended amount of physical activity (Czaja et al., 2019).

2.2 Technologies for enhancing physical activities

The increased awareness about the importance of physical activity contributes to the desire of the individual to understand the level of activity s/he performs and to be able to analyze various measures on the level of his/her activities (Andre & Wolf, 2007). Technologies and sensors for monitoring may allow individuals to evaluate objectively their type and level of physical activity(Andre & Wolf, 2007; Da Silva & Galeazzo, 2013; Sebestyen, Tirea, & Albert, 2012). It may support their will to increase their physical activity level as well as the correctness of their training (Andre & Wolf, 2007; Da Silva & Galeazzo, 2013; Sebestyen et al., 2012).

Different technologies for monitoring the physical activity level of people such as accelerometer, heart rate and pedometer (Andre & Wolf, 2007) have been developed (***Table 2)***. The technologies and techniques spectrum vary from objective and expensive to subjective and simple measures (Andre & Wolf, 2007; Da Silva & Galeazzo, 2013). Each technology offers different levels of accuracy, reliability, and comfort (Andre & Wolf, 2007). A variety of technologies has been implemented in games, smartwatches, smartphones and more (Sebestyen et al., 2012).

2.2.1 Applications for increasing physical activity for older people

Despite the many available applications for increasing physical activity most are not suitable for the older adults (Brox et al., 2016) since they lack consideration of older adults' perceptual capabilities in the design (Mitzner, Smarr, Rogers, & Fisk, 2015). Most of those age-related declines are connected with vision, audition, haptics and physical strength (Mitzner et al., 2015).

The demand for these applications is growing (Broekens et al., 2009; Webster & Celik, 2014) as a result of the rapid aging of the world population (United Nations, 2017). The main applications for increasing physical activity are presented in ***Table 3***.

Table 2: Physical activity monitoring devices

Device	Description	Wear able	Advantages	Disadvantages	References
Activity Watch	Wearable device or application for monitoring, tracking and recording physical activity of a user throughout a day, such as distance walked or run, calorie consumption, and in some cases heartbeat and quality of sleep. In addition, they allow goal setting that provides essential feedback that serves to increase self-awareness that can lead to behavioral change. The activity watch designed for use by individuals interested in fitness, health, and weight control. The device includes several different monitors of physical activity such as, heart rate and accelerometer**.**	Yes	• Suitable for outdoor • Combines several indicators	• Required across the chest or the hand to maintain good skin contact (for Heart Rate)	(Altamimi, Skinner, & Nesbitt, 2014; Guo, Li, Kankanhalli, & Brown, 2013; Trost, 2007)
Intelligent Phones	Intelligent phones are equipped with acceleration and localization sensors. Acceleration is useful to determine the state or the kind of activity and the position of the body (standing or sitting). The availability of intelligent phones, fitness applications for mobile and map information, gives motivation to use it as a fitness-monitoring device.	Yes	• Popular • Ubiquitous	• Information provided is noisy	(Buttussi & Chittaro, 2010; Sebestyen et al., 2012)
Kinect	A 3D depth camera that incorporates a depth sensor, a color camera, and a four-microphone array that provide full-body 3D motion capture, facial recognition, and voice recognition capabilities. The sensor recognizes the user's full body movement. One of the applications of Kinect is Skeletal Tracking, which allows recognizing people and following their actions. In addition, it can locate the joints of the tracked users in space and track their movements over time. Before the Kinect, such methods required a complex and costly hardware setup and interfered with the observed scene. In general, Kinect should be acquired within 1~3 m distance to the sensor. At larger distances, the quality of the data degraded by the noise and low resolution of the depth measurements.	No	• Real time output • Distinguish between different positions • No need to put anything on the body • Suitable for home environments • Compact • Portable	• Programming required to operate • Not suitable for outdoor environment • No system itself (need a computer)	(Dutta, 2012; Khoshelham, 2011; Oikonomidis, Kyriazis, & Argyros, 2011; Zhang, 2012)

Motion Capture / Motion Tracking	Technology for recording the movement of objects or people by cameras and markers. It is used in military, entertainment, sports, medical applications, and for validation of computer vision and robotics. Using that information to animate digital character models in 2D or 3D computer animation.	Yes	• Low latency • Close to real time • Results can be obtained • Cost-effective • Provides more realistic animation	• Cost • Setup • Calibration • Requires the subject to wear special clothing or specific shoes • Specific hardware and special programs are required	(Chalvatzaki, Papageorgiou, Tzafestas, & Maragos, 2017; Field, Stirling, Naghdy, & Pan, 2009)

Table 3: Applications for enhancing physical activity with the older adults

Technology	Description & Purpose	Category	Interaction Modality	Feedback for User	Activity Monitoring & Performance Measure	Reference
Exergames for Mobility	Developed fun and motivational exergames particularly targeting older adults in a user centered approach. Includes seven Kinect games, Walking app and a professional portal. The purpose is to promote mobility and keep older adults active by encouraging older adults to be more physically active and motivate them to move more.	Exercise Game	Visual screen display, Fitbit display	Utilized number of persuasive strategies based on positive reinforcements, the users' past behavior, social influence, feedback and personalization. Walking app – the users can set personal and group goals.	The exergames used motion sensors. Walking app used Fitbit to measure the users' steps. Social walking game where the group must reach a group goal while walking outdoors.	(Brox et al., 2016)
Virtual Reality Simulator	Combines virtual reality and body area network for generate application that allows seniors to control an Unnamed aerial vehicle using only the movement of their arms in a virtual environment.	Exercise; Health	Google Cardboard	The simulation responds appropriately according to the information that the nodes on each arm send automatically. Nodes on each arm that send information automatically to the phone, and the simulation will respond appropriately to it.	Nodes on each arm that monitoring the activity.	(Crespo et al., 2016)

Smartphone application	STARFISH application enables the users having accurate self-monitor their physical activity as measured by daily step counts, incorporated goal setting, action planning, feedback and social support.	Exercise	Smartphone screen	The app provides the users real-time step counts.	Inbuilt accelerometers	(Paul et al., 2017)
Dance video game	A metal dance pad was connected to a desktop computer using USB. The video game is projected on a white wall with a beamer. In addition, a scrolling display of arrows moving upwards across the screen cued each move, and the users need to execute the indicated steps when different songs play.	Exercise Game	Visual screen display	The game provides the users real-time visual feedback.	Electronic sensors in the dance pad detected position and timing information. In addition, it is used for control progression of performance through the beats per minute and the difficulty level.	(Pichierri, Coppe, Lorenzetti, Murer, & de Bruin, 2012)
Distributed software architecture	The aim is to support Long Term Care in-house medical protocol by allowing remote interaction with the older adult to assign exercise games, verify progresses in mobility, and monitor health/environmental parameters.	Rehabilitation; Exercise Game	Video and audio - allows remote interaction between older adult and caretaker.	Sequence of skeleton position is display on the screen. If the skeleton is too off the required asset, the skeleton drawn in red in order to provide immediate visual feedback and an alarm raised on the screen.	Multiple Kinect devices that monitor users' status. For example, if the elder falls and cannot get up, does not wake up in the morning. Additionally, an alert can be raised in real-time.	(Maggiorini, Ripamonti, & Zanon, 2012)
Embodied Conversational Agent - ECA	A computer-based physical activity program with a pedometer control condition in sedentary older adults.	Exercise; Health	Portable tablet computers with touch screens. Animated computer characters that simulate face-to-face conversation using voice, hand gesture, gaze cues, and other nonverbal behavior.	The virtual coach provides positive reinforcement if warranted.	Measured the number of daily steps, using a digital pedometer.	(Bickmore et al., 2013)

Flowie	A persuasive virtual coach that motivate seniors to walk more	Exercise; Health	Graphical user interface with touch.	A flower image shown in the general overview gives high-level feedback on the activity level in relation to the step goal.	Pedometer - measuring the activity levels. A set of step goals	(Albaina et al., 2009)
Interactive Computer Game Exercise	A dynamic balance exercise application coupled with video game play, using a center of-pressure position signal as the computer mouse. The interactive gaming system, including the pressure mat and interface and the laptop computer.	Exercise Game	Visual display and audio	Positive reinforcement provided to both participant and therapist via a sound that played when an object caught or the balloon burst, and a display showed success rates.	Recordings of the raw foot pressure signals.	(Szturm, Betker, Moussavi, Desai, & Goodman, 2011)
Wii Fit	The Nintendo Wii Fit console is an interactive video exercise game that proposes tests, games and exercises that involve all body parts. Aims to improve balance in the older adults.	Exercise Game	Visual screen display	Wii Fit provides the participant with immediate feedback about the movements of the body's center of gravity, a key measure of balance control.	All exercises performed on the Wii Balance Board, which has pressure sensors that can measure a user's center of gravity and weight.	(Franco, Jacobs, Inzerillo, & Kluzik, 2012; Pierangeio Dell' Acqua, Leonie Verheijden Klompstra, Tiny Jaarsma, 2013; Toulotte, Toursel, & Olivier, 2012)

2.2.2 Robotic applications for enhancing physical activities

Several research efforts have been channeled into developing robotic applications to increase physical activities (Cruz-Sandoval et al., 2018; Fasola & Mataric, 2013; Guneysu & Arnrich, 2017; Ramgoolam et al., 2014). Some of these efforts focused on children (Guneysu & Arnrich, 2017), some on adults (C. Park & Kim, 2016; Ramgoolam et al., 2014) while others focused on older adults (Caic, Avelino, Mahr, Odekerken-Schroder, & Bernardino, 2019; Fasola & Mataric, 2013; Lewis et al., 2016a; Lotfi, Langensiepen, & Yahaya, 2018). Some of the research work employed user feedback which contributed to interaction improvement. Major robotic applications for enhancing physical activities are presented in ***Table 4*** along with the motivation and description of robotic applications.

2.2.3 Challenges with robotic application for enhancing physical activities of older adults

Among several applications for enhancing physical activities of older adults which are presented in ***Table 4***, some were robotic applications (Bedaf et al., 2015). The major challenges observed while evaluating the interaction between the older participants and the robotic coach were related to the type of physical activity, length of sessions, creativity during the sessions, motivating the adults during the sessions and the form of the feedback given by the robot (Lewis et al., 2016b)

Due to the key importance of motivation in activity with robots, particular attention will be paid in this thesis to the form of the feedback given by the robot to the older adult during the exercise sessions to ensure that the older adult remains motivated. Specifically, the research focuses on **what forms of feedback should be given**, **how should the feedback be given** and **when should the feedback be given** to improve the experience that the older adults have while interacting with the robot during the exercise sessions? The hypothesis is that improved feedback can lead to an interactive, pleasant and enjoyable robot enhanced exercise session for the older adults. A comparative study was also carried out to explore **user preferences while training with the two forms of humanoid robots** and to determine which of the robots gives better satisfaction.

Table 4: Robotic applications for enhancing physical activity

Robotic Application	Description & Purpose	Motivational framework	User Feedback	Outcome	Reference
Socially Assistive Child-Robot Interaction in Physical Exercise Coaching	Design and implementation of an autonomous human robot interaction system to engage children in performing several physical exercise motions by providing real-time feedback and guidance. The purpose is to validate the effectiveness of the system in motivating and helping children to complete physical exercises.		The robot provides real-time feedback, encouragement and guidance. It gives verbal feedback to explain how to do the exercises, gives positive feedback when the user accomplishes the motion and correct the users if he have not completed the motion (one group - Verbal-only corrective, second group - Repetition feedback.	The children rated the interaction highly in terms of enjoyableness and rated the robot exercise coach highly in terms of social attraction, social presence, and companionship.	(Guneysu & Arnrich, 2017)
Towards a Social and Mobile Humanoid Exercise Coach	Compare the effects on young adults of coaching delivered by human health coach vs. a social and mobile humanoid robot health coach.	It offered instructions for appropriate technique and encouragement.		The robot coach was as successful as the human coach at socially and motivationally engaging participants during the workouts.	(Ramgoolam et al., 2014)
Robot Social Skills for Enhancing Social Interaction in Physical Training	Testing the effect of a robot using social skills when interacting with humans. Nao demonstrated seven yoga and physical exercise poses with different levels of difficulty to human participants (aged 20 - 60 years old).		The robot provides verbal motivational feedback to the user autonomously according to the motion recognition.	Robot social and interactive skills including feedback, mutual gaze and social distance should be taken into account when exercising by a robot.	(C. Park & Kim, 2016)

***A Socially Assistive Robot Exercise Coach for the Elderly**	A robot is designed to engage older adult users in physical exercise. Robot whose purpose is to monitor, instruct, evaluate, and encourage users to perform simple physical exercise. The robot evaluates the user performance and gives the user real-time feedback. The purpose is to compare between user evaluations of similar physically robot and virtually embodied coaches.	Focused on providing a variety of challenging exercise games of varying levels of difficulty. Focused on the fluidity of the interaction. Incorporated indirect competition into the system design by having the robot periodically report the user's high score during each of the exercise games. Provides positive feedback to the user in the form of praise upon correct completion of the given exercises. Never gives negative feedback so as to avoid diminishing intrinsic motivation to engage in the exercise task. Additionally, the robot reporting the user's personal high scores during two of the three exercise games played.	Using the user's name, it provides real-time corrections feedback according to the performance of the user and the level of the performance history during the games. Additionally, it congratulates the user in response to each successful imitation.	Clear preference among the participants for the physically embodied robot over the virtually embodied robot.	(Fasola & Mataric, 2013)
***Evaluating Human-Robot Interaction Using a Robot Exercise Instructor at a Senior Living Community**	Pilot study of Nao, an agent-based exercise robot for five senior residents and five staff members in a senior living community. Nao provided an introductory, warm-up routine and then proceeded to lead the group through exercises focusing on leg, arm, feet, hands, neck, eyes, and full body. Then Paro (robotic model of a baby harp seal) made a session. The purpose was to evaluate the performance of the resident group and the attitudes, acceptance, and opinions of both groups.			The senior residents moderately accept the robot as a group exercise leader and staff members are cautiously enthusiastic about the idea.	(Lewis et al., 2016a)

***Towards Social Robots that Support Exercise Therapies for Persons with Dementia**	Preliminary user study of robot that support exercise therapies for person with dementia. The robot motivates and encourages the users to perform the exercises.		The robot speaks to the users and make different gestures to encourage them.	The users imitate the robot's movements and were engage by the robot. The use of social robot to support an exercise therapy seems feasible. A one term research with more participants needed.	(Cruz-Sandoval et al., 2018)
***Robotic Versus Human Coaches for Active Aging: An Automated Social Presence Perspective**	Empirical study examines the social perception of older adults about human versus robotic coaches (Vizzy robot). The users should play in exergames, the actor (human/robot) introduce the activity, invite the users to join the game, instruct how to play the game and motivate the users.	According to the user progress, encouragement him verbally.	According to the performance of the player, gives red visual feedback and success and failure sounds.	Human coaches preferred since perceived warmth and competence relative to robotic coaches.	(Caic et al., 2019)
***Socially Assistive Robotics Robot Exercise Trainer**	The double robot, a mechanoid robot with an iPad, was an exercise trainer. The purpose of the robot is to engage, coach, assess and motivate the elderly in physical exercises.	Motivates the participants according to their performance with the feedback.	Real-time feedback, according to the performance of the user, gives facial feedback and voice notes.	Participants reported satisfaction and willingness to recommend the system to others.	(Lotfi et al., 2018)

* Specifically, for older adults

2.3 Feedback

"Feedback is information about reactions to a product, a person's performance of a task, etc. which is used as a basis for improvement" (Dictionary, 1989). Usually, feedback describes the gap between intended and actual user performance (Pérez-Quiñones & Sibert, 1996).

In order to meet the psychological and cognitive processing needs of humans, which are complex systems, humans require feedback from others (Kendall & Kendall, 2010). Feedback increases human confidence (Pérez-Quiñones & Sibert, 1996). As a result, a system that provides feedback can help users correct mistakes and reinforce concepts and procedures (Czaja, Rogers, Fisk, Charness, & Sharit, 2009). If feedback is not provided during a session, the user may become unmotivated, bored, or, unsure whether the task performed was successful (Dix, Finaly, Abowd, & Beale, 2004).

Adequate feedback is an important source for increasing motivation for users of a system (Czaja et al., 2009; Garber, 2008). Anytime users interface with machines, they need feedback about the progress of their work (Pérez-Quiñones & Sibert, 1996). Feedback is an integral element in a system and it is necessary to be aware of the human need for it (Pérez-Quiñones & Sibert, 1996), it helps to make smooth interaction between robot and human (Nicole Mirnig et al., 2014), and increases trust of human in robots during collaborative task (Stadler, Mirnig, Weiss, & Tscheligi, 2012). It should also be informative (Dix et al., 2004). Providing excessive or ill-timed feedback can disrupt the user of the system (Czaja et al., 2009; Doisy, Meyer, & Edan, 2014b; Kendall & Kendall, 2010). As a result, people can overload working memory or focus on the wrong things (Czaja et al., 2009; Kendall & Kendall, 2010).

2.3.1 Feedback in human-robot interaction

Feedback is an important part of human-robot interaction (Mirnig et al., 2011). Its influence on the success of the communication between human and robot has been tested (Mirnig et al., 2011). In their experiment, it was shown that a robot that provides feedback was more likely to be perceived as a social communication partner. Additionally, users that did not receive feedback during the interaction stated that they would like to receive feedback from the robot. Human-robot-interaction using feedback is improved as compared to interactions without feedback (Mohammad & Nishida, 2007).

During training, positive and negative feedback should be given in order to reduce repeated errors, particularly for older adults who have been used to specific patterns or order of doing things for several years. Adequate and immediate feedback has the potential to improve their performance. In general, this population will benefit from face-to-face feedback especially in the early stages of using a system (Czaja et al., 2009).

Feedback provided to the users could be in different forms which could be varied with regards to mode, timing and other dimensions of the feedback.

2.3.2 Mode of feedback

Diverse types of feedback can be given by a system to the users (Olatunji et al., 2019). The types include tactile, haptic, auditory and visual and a combination of them (Ajoudani et al., 2018; Cen/Cenelec, 2002; Jacko et al., 2004; Rosati et al., 2013). The performance of the users with auditory, haptic and visual feedback was better than the performance of the users with only visual feedback (Jacko et al., 2004).

Auditory feedback can influence better communication between the robot and the users. It can also be complementary to the feedback available visually (Rosati et al., 2013). This feedback should include encouragement and support that can increase the user's motivation (Rosati et al., 2013). Furthermore, audio feedback that is properly designed can improve users' motivation while performing motor exercises that are task oriented (Rosati et al., 2013).

Visual feedback suitable for remote human-robot collaboration (Ajoudani et al., 2018) could include LEDs which could help humans better understand the state and the action of the robot (Baraka & Veloso, 2018). This can also improve the collaboration between the human and the robot (Baraka & Veloso, 2018).

Facial expression can support giving feedback in the interaction between a human to a robot (Lang, Hanheide, Lohse, Wersing, & Sagerer, 2009). During the interaction between persons, the conversation includes speech and facial expressions. The facial expression can provide useful information (Lang et al., 2009) and has the potential to make the robot's behavior better understandable (Van Breemen, 2004). In the research of Mirnig et al., 2014, they compared a task of adults for a robot with facial expression and without. It was shown that robot who provided facial expressions feedback was considered more intelligent by the users and the task was rated as more attractive (Mirnig et al., 2014). However, the results did not have statistical significance.

Finding the suitable mode of feedback is crucial to improving the interaction between the user and the robot. This will be explored in this thesis in the context of physical training of older adults.

2.3.3 Timing of feedback

The timing of the feedback can be immediate or delayed, frequent or infrequent (Czaja et al., 2009), continuous or discrete. Suitable timing of feedback advances natural flow of communication which helps the user accept the robotic agent communication partner (Mirnig, Weiss, & Tscheligi, 2011). Feedback has to be provided to the users at an appropriate time because ill-timed feedback could confuse the user (Mirnig et al., 2011).

Feedback timing could also be continuous or discrete. Previous studies have revealed that continuous feedback can improve the trust of the user in the robot (Agrawal & Yanco, 2018; Sanders, Wixon, Schafer, Chen, & Hancock, 2014). It can also decrease the user’s workload (Agrawal & Yanco, 2018). However continuous feedback could lead to presentation of too much information (Doisy, Meyer, & Edan, 2014a). This can result to information overload and decrease the performance of the users (Doisy et al., 2014a).

Finding the suitable timing of feedback is crucial to improving the interaction between the user and the robot. This will be explored in this research in the context of physical training of older adults.

3 Methods

3.1 Overview

The system design is focused on motivating older adults to regularly observe and complete their exercise sessions. The system effectiveness depends on the robot type, timing, and mode of feedback which will encourage the users to cooperate and complete the training. The most suitable timing and mode of feedback for improved quality of interaction were therefore explored. Correcting the older adults if the physical activity is not being properly done keeps the older adults aware of the actions and intentions of the robot at every point of time. Existing literature review suggests that social interaction could be improved through feedback (Czaja et al., 2009; Garber, 2008; Mirnig et al., 2014). This hypothesis was tested through preliminary and main studies as described below.

3.2 System development

3.2.1 The overall system

The system design includes a Kinect camera connected to a humanoid robot (***Figure 1)***, which performs before the users. The monitoring of the user's performance and exercise sessions was conducted using an RGB-D camera (Kinect). The depth camera provides a more accurate view of the user's movements compared to a conventional RGB camera. This aids the feedback process by giving the users information regarding their performance. The robotic coach was programmed to instruct the users for the different forms of exercises. Two types of humanoid robots (Nao and Poppy) were used as robotic coaches for comparison purposes. The Microsoft Kinect was used as the RGB-D camera for tracking performance because it was accessible, applicable and had a software development kit equipped with skeleton tracking. The developed algorithm included parallel programming of each robot with the Kinect.

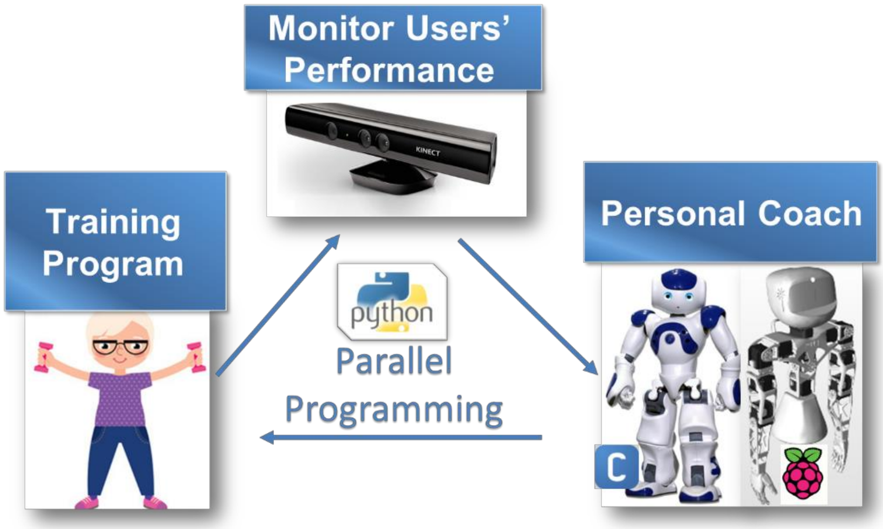


Figure 1: The developed system

3.2.2 Monitor users' performance

Users' performance was monitored with the Kinect which was programmed to extract the users' skeleton. The skeleton contains the 3D point position of 25 joints of the user ***(Figure 2)***.

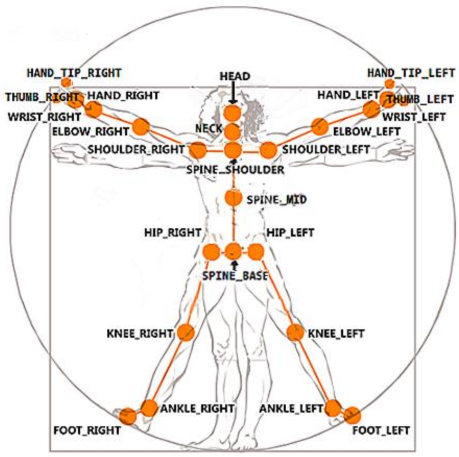


Figure 2: 25 joints' positions of the skeletal tracking relative to the human body

Each position includes a coordinate system (X, Y, Z). X corresponds to the width, Y corresponds to the height and Z to the depth. From the positions with the following equations;

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$\cos B = \frac{a^2 + b^2 - c^2}{2ab}$$

The distances (d) and the angles between joints (B) were calculated. The developed algorithm checked if the user made the correct movement using the following algorithm ***(*Algorithm 1*)***.

Algorithm 1- Algorithm for Kinect Detection

Algorithm for Kinect detection

get joints, $\boldsymbol{right_{joint1}}, \boldsymbol{right_{joint2}}, \boldsymbol{right_{joint3}}, \boldsymbol{left_{joint1}}, \boldsymbol{left_{joint2}}, \boldsymbol{left_{joint3}}$
compute angles:
    $\boldsymbol{angle_{right}(right_{joint1}, right_{joint2}, right_{joint3})}$
    $\boldsymbol{angle_{left}(left_{joint1}, left_{joint2}, left_{joint3})}$
compute depth difference:
    $\boldsymbol{depth_{right}(right_{joint1}, right_{joint2})}$
    $\boldsymbol{depth_{left}(left_{joint1}, left_{joint2})}$
if $\boldsymbol{angle_{right} > upperbound \; \& \; angle_{left} > upperbound}$ & $\boldsymbol{hands_{down}}$
    if $\boldsymbol{depth_{right} < lowerbound \; \& \; depth_{left} < lowerbound}$
        update actions and state of hands:
            $\boldsymbol{user_{repetition} \leftarrow user_{repetition} + 1}$
            $\boldsymbol{hands_{up}}$ ← state of hands
if $\boldsymbol{angle_{right} < lowerbound \; \& \; angle_{left} < lowerbound}$
    if $\boldsymbol{depth_{right} < lowerbound \; \& \; depth_{left} < lowerbound}$
        update state of hands:
            $\boldsymbol{hands_{down}}$ ← state of hands
        if $\boldsymbol{user_{repetition} \geq repetition_{aim}}$
            end exercises
save_data ($\boldsymbol{height_{right}, height_{left}}$**)**

3.2.3 Operations of the robot coach

The two robot coaches (Nao and Poppy) were programmed in the Python programming language. The Nao robot was programmed using the *naoqi* library while the Poppy robot was programmed with the *pypot* library. The speech of the robots was implemented using existing algorithms in these libraries. A screen running on raspberry pi was added to the poppy robot to provide visual (facial) feedback ***(Figure 3)***.

Figure 3: Poppy facial expressions

The session begins with the robot standing in front of the user and introducing itself. The robot waits until the user stands in front of it. It introduces itself as the user's exercise coach. It asks the user to raise his right hand if he/she wants to start the training. Then, the robot will start the session with instructions on what exercise should be done and also demonstrates how it should be done. At the end of the session, the robot will thank the user for his/her participation and say goodbye. The main logical flow of the process is illustrated in ***Figure 4.***

A video of the robot can be seen at https://www.youtube.com/watch?v=mEBYqd6sgmI&t=1s

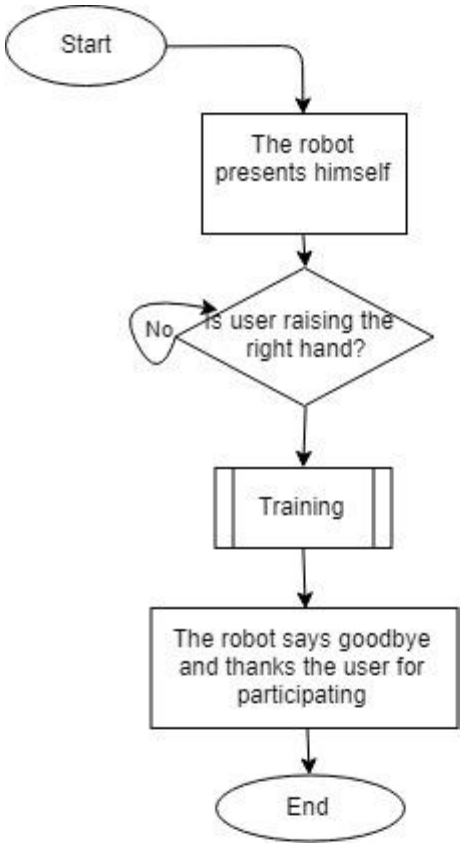


Figure 4: Logical flow of main process

The session lasts about 10 minutes. The robot provides feedback according to user performance detected by the Kinect. If the user performs the exercise well, the robot provides positive feedback. In the discrete feedback condition, the robot will give positive feedback at the end of the exercise, while in the continuous feedback condition, the robot will also count every time that the user made the right repetition. If the user performs the exercise incorrectly, the robot gives corrective feedback and asks if the participant wants to try the exercise again or move on to the next exercise.

The process for the strength and balance exercises are given in ***Figure 5***.

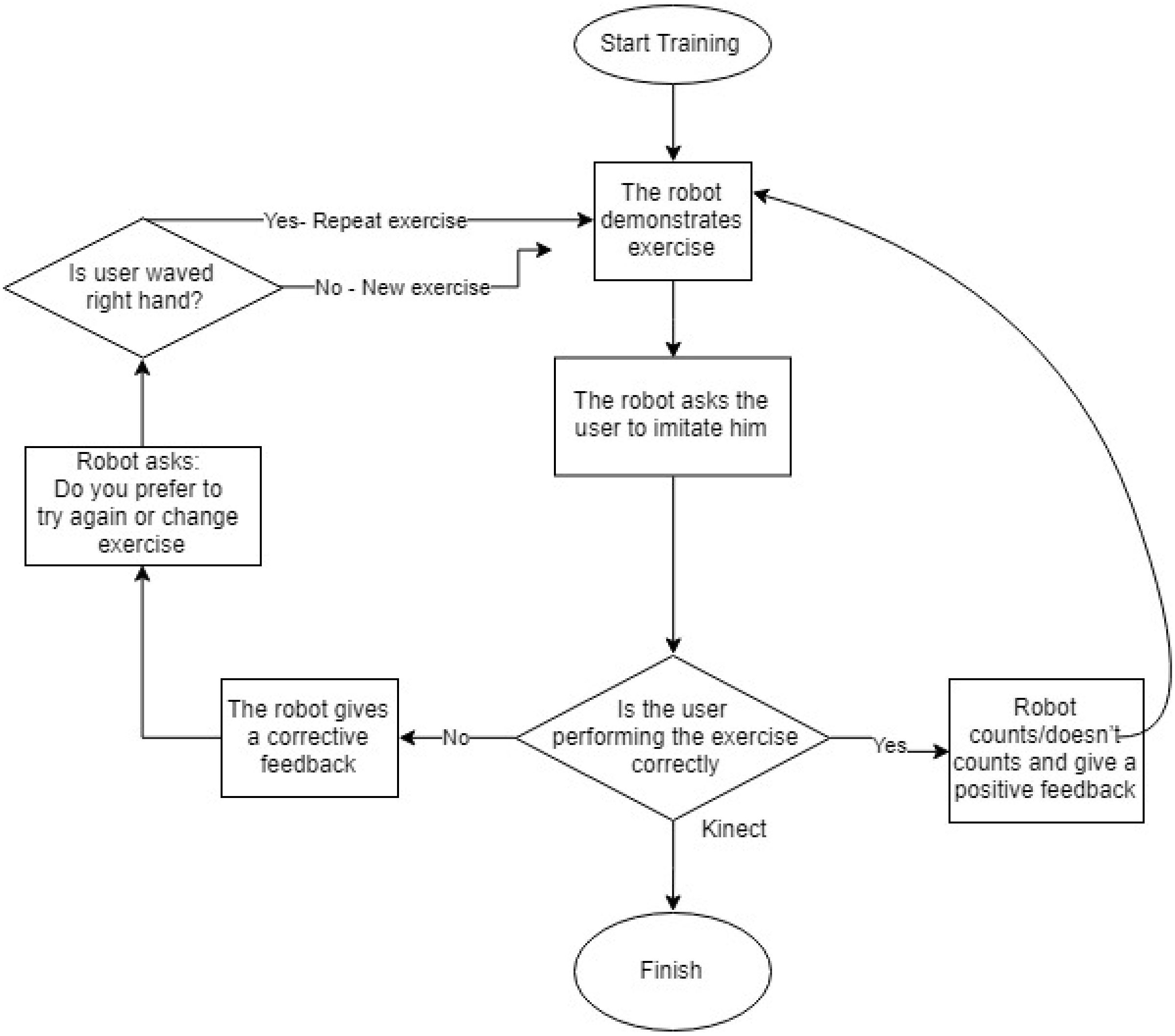


Figure 5: Logical flow of strength / balance exercises

3.2.4 Development of the exercises

The developed training program includes balance and strength exercises that are recommended by the National Institute on Aging (NIHI) (https://www.nia.nih.gov/health/exercise-physical-activity). These exercises were chosen because instability and muscle weakness are widespread problems among older adults. This results in falls among older adults along with difficulty and inability to perform basic activities. Some of these basic activities include getting out of bed or from the chair, opening a bottle, carry objects and so on. Muscle strengthening and improved balance can help prevent falls and help to make daily activities easier. This makes balancing and strengthening exercises recommended for older adults.

3.2.4.1 Exercises of Preliminary Experiment

Six exercises were developed for the preliminary experiment (**Figure 6*)***. The strength exercises include raising elbows, sidearm raise both hands and each time one hand. The stability exercise includes side leg raise.

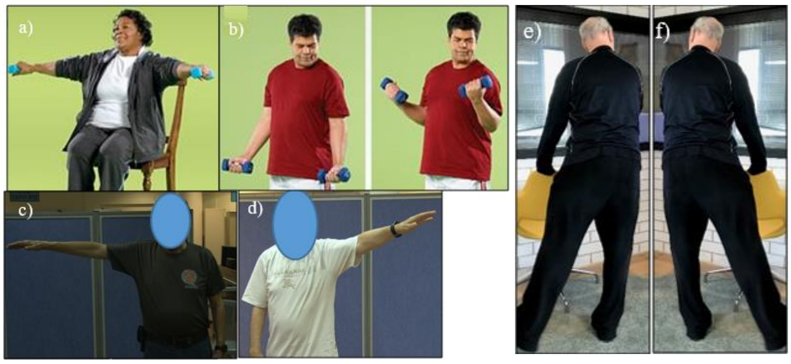


Figure 6: Strength and balance exercises: a) raising arms horizontally b) bending elbows c) raising right arm horizontally d) raising left arm horizontally. Balance exercises: e) left leg raise f) right leg raise.

3.2.4.2 Exercises of Main Experiment

Eight exercises were developed for the main experiment (***Figure** 7)*. The two balance exercises from the preliminary experiment were removed since only the torso version of the Poppy robot was available. The strength exercises involve bending elbows, raising arms and bend elbows, raising arms and bending elbows 90 degrees, raising arms forward, raising arms horizontally, raising arms horizontally and turning hands, horizontal raising each arm.

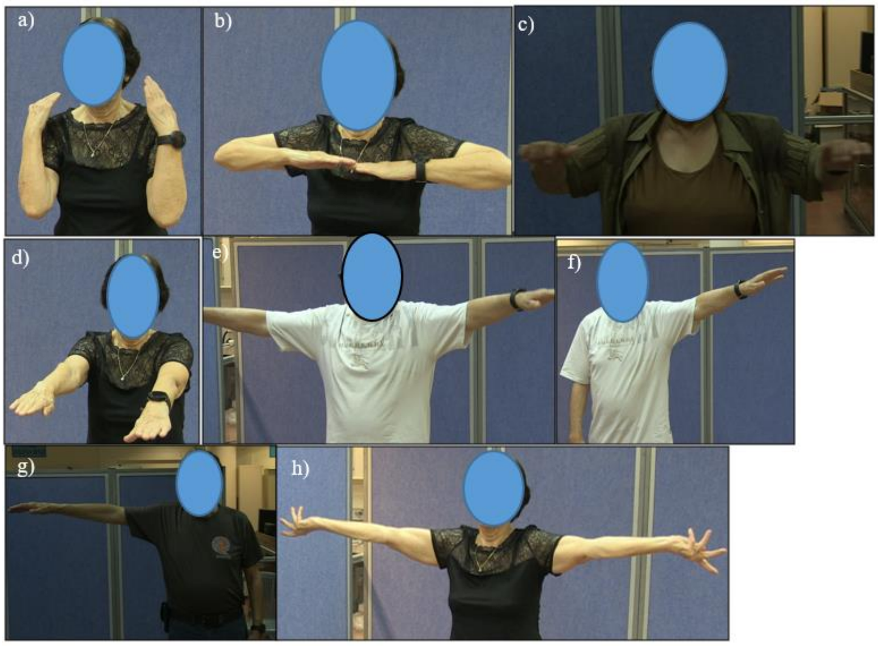


Figure 7: Strength exercises: a) bending elbows b) raising arms and bend elbows c) raising arms and bending elbows 90 degrees d) raising arms forward e) raising arms horizontally f) raising arms horizontally and turning hands g) raising left arm horizontally h) raising right arm horizontally.

3.3 Physical training coach

3.3.1 Nao robot

Nao ***(Figure 8)*** is an autonomous, programmable humanoid robot developed by Aldebaran-Robotics, a French robotics company. Its height is 57cm and its weight is 4.3 kg (Gouaillier et al., 2008; SoftBank, n.d.) Nao's main technical features include 25 degrees of freedom, sensors in its head, hands and feet, sonars, 4 directional microphones and loudspeakers, and two cameras. The operating system is NAOqi based Linux (SoftBank, n.d.).

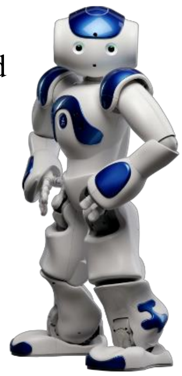


Figure 8: Nao robot

3.3.2 Poppy torso robot

Poppy *(***Figure 9***)* is an open-source 3D printed humanoid robot. Its height is 84 cm and its weight is 3.5kg (Lapeyre *et al.*, 2014). Poppy was designed to be anthropomorphic with 25 degrees of freedom (DOF) including a 5 DOFs articulated trunk (Devanne & Nguyen, 2017) and LCD screen for display.

Figure 9: Poppy robot

3.3.3 Examination of Nao's programming alternatives

The existing Nao robot in the lab is an academic version with ATOM INTEL processor and NAOqi 2.4 operating system. The physical version of the robot is HEAD5 with stereoscopic head, intended for research use. This stereoscopic head uses the two cameras of the robot and allows the robot to see in 3D.

The Nao robot can be programmed in several programming languages. Prior to choosing the preferred programming language, the advantages and disadvantages of the programming languages were examined as well as the language suitability.

Main possible programming languages (Aldebaran, no date)**:**

1. C # - an advanced programming language developed by Microsoft. This language does not have an SDK that is compatible with NAOqi version 2.1 of NAO but only to an earlier version (1.1) It should be noted that the working environment suitable for this language is Visual Studio, but the robot can be programmed in a Visual Workspace Studio 2010.
2. Python - a simple-to-use dynamic programming language that allows good robot capabilities. There are examples and more detailed explanations throughout the web as well as existing SDK files for all released robot versions. Furthermore, previous projects used this language.
3. Java - An advanced, object-oriented programming language that can run on any computer and any operating system. This is not a common programming language for the NAO robot, and it does not have all of the programming abilities.
4. C++ - Object-oriented language. For this language, there are examples and most detailed explanations throughout the network as well as existing SDK files for all released robot versions (up to version 2.1).
5. Choregraphe - This is a dedicated programming environment for the use of the NAO robot. With this software, which comes with the robot and contains built-in code snippets in the Python programming language, the robot can be programmed using a visual user interface. Robot programming in this software is quite intuitive and does not require the use of the SDK. There are many projects across the web that use this software, but it is limited in terms of its capabilities (cannot use the function "Speech

Recognition" because a robot with a version 2.4 operating system), is problematic for connecting with the Kinect and to make complex program.

In conclusion, following the many examples and extensive use of Python in Nao programming on the network, along with the language advantages and rapid development it allows and the author's prior knowledge of the language, Python was selected to program the Nao robot. In addition, some specific functions in Choregraph were imported to the Python programming interface.

3.3.4 Examination of Poppy's programming alternatives

The company developed the *pypot* library which makes it easier to program the robot through Python. (Lapeyre, et al., 2014). As a result, the system was programmed in Python.

3.3.5 Examination of simulator alternatives

Due to a failure in the real robot, it was not possible to carry out the preliminary experiment with the real robot as initially planned and programmed. Instead a simulated robot was utilized.

Two alternatives for simulators were examined:

1. Webots: A robot simulator that provides a complete development environment to model, program and simulates robots. It has the option to change the background, it has models of speech and operating Nao LEDs. Using the simulator speech and LED models to demand a dramatic change in the coding because it requests a different version of Python then the Naoqi ***(*****Figure 10*****)***.
2. Choregraph: It is a structured simulator that is included in the Nao package. It is a simple and clear simulator that includes only movement and text. The simulator includes the Nao robot on a blue background ***(*****Figure 11*****)***.

Due to lack of time, incorporating the additional models in Webots was not feasible. A speech recognition through the Python model that required parallel programming was developed. As a result, the decision between which simulator to use depended on the background of the system. To accommodate the older population, it was decided that a simple background that will be less cluttered and will help them focus on the robot itself rather than the environment around will be used.

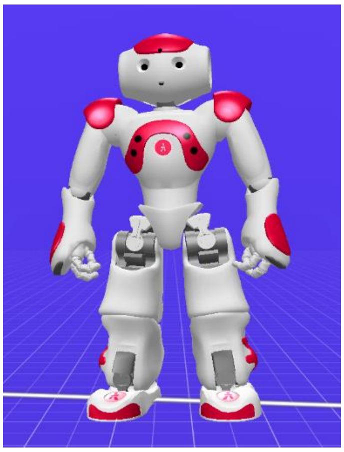


Figure 11: Choregraphe

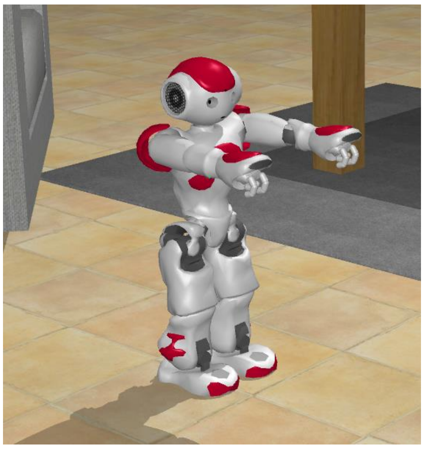


Figure 10: Webots

3.3.6 Examination of Kinect programming alternatives

The Microsoft Kinect sensor for windows integrates a depth sensor, color camera, and a microphone and is a low-cost sensor (DiFilippo & Jouaneh, 2015; Zhang, 2012). The sensor can provide full-body 3D motion capture, skeleton data, voice recognition and facial recognition (Zhang, 2012).

The common languages to program the Kinect are C++, C#, and Python.

The Kinect was programmed in Python to easily connect to the physical robot application. Existing programming applications reveals that running a program on the same language gains the advantage of not requiring a protocol between two languages. As a result, the system has more probabilities to run without problems.

3.4 Preliminary study

3.4.1 Experimental description

The design of the preliminary experiment included only verbal feedback. The independent variable in the experiment was the timing of feedback. Each participant experienced two conditions for the timing of feedback - continuous and discrete feedback.

The dependent variable was the effectiveness of the exercise sessions which was measured subjectively as will be explained in the ***Evaluation*** (section 3.4.4).

3.4.2 Procedures

The 10-minute session took place in a home-like environment. Each user was engaged with the robot and asked to perform the exercises demonstrated by the robot. The user was prompted by the robot to imitate it. There was an introduction session by the robot as described in ***Figure 4***. Then the robot proceeded to the exercises. The exercises were monitored by the Kinect to ensure compliance with the robot's instructions. BGU Ethics committee approved the research before the experiments were carried out ***(Appendix A*** - BGU ethical committee approval forms***).***

3.4.3 Participants

The study population included 10 older adults (4 females and 6 males) aged 67 and over, without any major physical limitation. Their physical fitness was assessed with a questionnaire specifically checking how physically fit they are (***Appendix B*** – Pre-questionnaires How physically active are you?). The participants were recruited by advertising via personal contacts (grandparents of friends who were notified of the research) and at BGU's Center of Digital Innovation healthy aging innovation lab (https://www.cdi-negev.com/project/the-healthy-aging-simulation-center/). All recruited participants filled the consent form independently.

3.4.4 Evaluation

The effectiveness of the interaction was assessed subjectively through questionnaires and short interviews regarding the users' experience. It involved questionnaires about their experience with the robot, technology acceptance and negative attitude toward robots.

The pre-trial questionnaire used was the Negative Attitudes Towards Robots Scale (NARS), TAP and How Physically Active Are You? ***(Appendix B*** – Pre-questionnaires***)***. NARS' questionnaire assists to examine the participants' perception of technology and robots, TAP's questionnaire which examines the participants level of technological knowledge while the last questionnaire will help in the assessment of participants' physical activity.

The final questionnaire includes questions about the participants' evaluations of the robot as an exercise coach and about his social attraction (***Appendix D*** – Post-questionnaires)

At the end of the session, an interview of 10 minutes (on average) was conducted to understand the assessment of the coaching, the interaction and the real robot, Nao ***(Appendix E*** – Post interview***)***.

The main experiment was designed based on the outcome of the preliminary experiment.

3.5 Main Study

3.5.1 Model

The model for the main study was designed based on the "Technology Acceptance Model" (Davis, 1989). The independent variables in the experiment were the timing and mode of feedback and type of robot. The dependent variables were the perceived usefulness, ease of use, attitude and behavioral intention to use the system as depicted in ***Figure 12***. These were measured objectively and subjectively as will be explained in the ***Evaluation*** section (section 3.5.5).

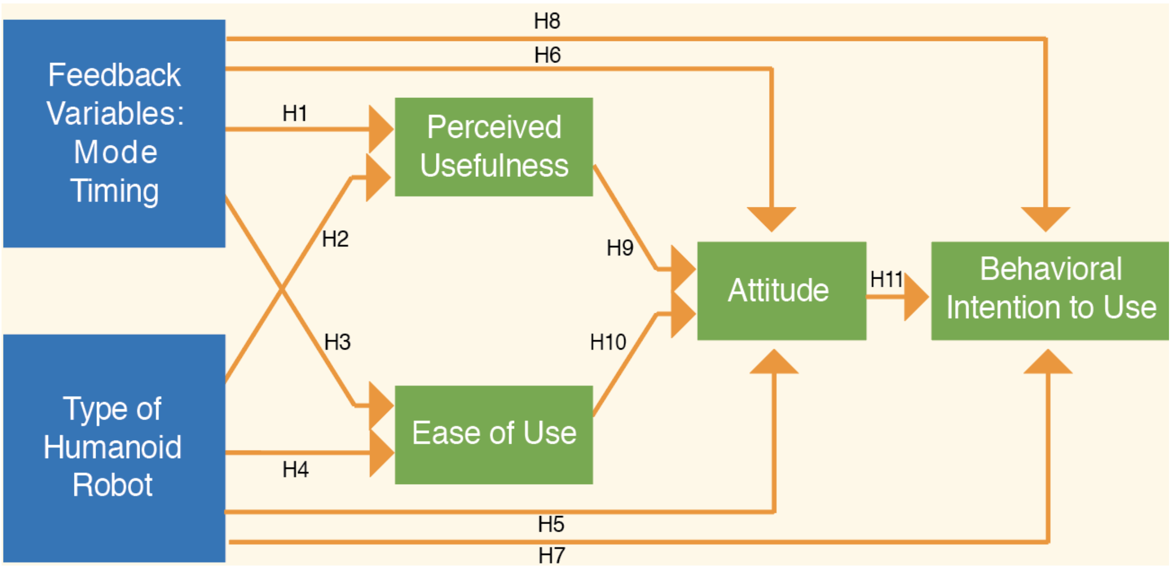


Figure 12: Model description

3.5.2 Experimental description

The design of the main experiment included three independent variables: mode of feedback (audio and visual), timing of feedback (discrete and continuous) and type of humanoid robot (Poppy and Nao), and included four groups (each group represented by different color). Each participant experienced one combination of mode and timing of feedback with two humanoids robots; Poppy and Nao as described in ***Table 5.***

Table 5: Experimental design

Mode\Timing	Discrete	Continuous
Audio	Poppy	Nao
	Nao	Poppy
Audio + Visual	Nao	Poppy
	Poppy	Nao

3.5.3 Procedures

The experiment included two sessions; each session included a different robot. In the sessions, the user was engaged with the robot to carry out the exercises demonstrated by the robot. The user was prompted by the robot to imitate him. There was an introduction session by the robot as described in ***Figure 4***. Then the robot proceeded to the actual strength exercise. The exercises were monitored by the Kinect to ensure compliance with the robot's instructions.

3.5.4 Participants

The study population included 32 old adults aged 70-88, 18 females and 14 males. All participants were without any major physical limitations and arrived in the lab independently. The participants were recruited by advertising via personal contacts (grandparents of friends who were notified of the research and friends of my grandmother), at BGU's Center of Digital Innovation healthy aging innovation lab (https://www.cdi-negev.com/project/the-healthy-aging-simulation-center/), at an older adult's local club in Beer Sheva, a local police pensioners club, BGU's older adults working force and previous older adults who performed experiments in our labs. All recruited participants contacted us and filled the consent form independently.

3.5.5 Evaluation

The dependent variables were assessed objectively and subjectively.

3.5.5.1 Objective performance measures

The objective measures detailed in ***Table 6*** were acquired by analyzing recorded videos of the sessions, measurements using a heart rate watch, and observations by the author documented along the experiments.

Table 6: Objective measurements

Dependent Variable		Measurement	References
Ease of Use	**Comfortability**	$HR\ change = HR\ after - HR\ before$	(Rani, Sarkar, Smith, & Kirby, 2004; Rani, Sims, Brackin, & Sarkar, 2002)
	Understanding	Reaction time - seconds it took participants to react to the robot's instructions	(Hellström & Bensch, 2018)
		Incorrect response	
		Question to clarify	
		Participant continued with the exercise after the robot had stopped	
Attitude	**Engagement**	Eye contact – The time that the participant looks at the robot during the interaction	(Sidner, Kidd, Lee, & Lesh, 2004)
	Adherence to training	Success rate = $\frac{Exercises\ completed}{Sum\ of\ exercies}$	

3.5.5.2 Subjective performance measures

The subjective measures were collected through questionnaires which involved questions about the participants' experience with the robot, technology acceptance and negative attitude toward robots.

The pre-trial questionnaire used was the Negative Attitudes Towards Robots Scale (NARS), and Technology Assessment Propensity (TAP) (***Appendix K*** – Pre-questionnaires). NARS' questionnaire assists to examine the participants' perception of technology and robots while TAP's questionnaire which examines the participants' level of technological knowledge.

The post trials questionnaires and the variables they assessed are presented in **Table 7**. The questionnaire based on Almere model (Heerink, Kröse, Evers, & Wielinga, 2010).

Table 7: Post trail questionnaires

Dependent Variable		Question
Perceived Usefulness		I would be willing to train with the robot again because it had value to me.
Ease of Use	**Comfortability**	I felt nervous during the activity
		I felt comfortable during the interaction
	Understanding	I understood the robot well during the interaction.
	Effort	I put a lot of effort into this activity.
Attitude	**Engagement**	I concentrated on the activity for the entire session.
	Trust	I felt like I could really trust this robot.
	Satisfaction	I was satisfied by the robot's performance during this activity.
	Enjoyment	I enjoyed the activity
Intention to Use	**Acceptance**	I would like to exercise with the robot in the future.

The final questionnaire includes questions about the evaluations of the robot as exercise coach and about its social attraction ***(Appendix M** – Final questionnaires**).*** All answers were ranked using a 5 point Likert scale (Allen & Seaman, 2007; Likert, 1932).

3.5.5.3 Analyses

The analysis and the preprocessing of the raw data was conducted with the following statistical programs: SPSS, RStudio, Excel. Generalized linear mixed model (GLMM) was performed for the objective dependent variables in order to the determine the influence of the independent variables on it. The target function was chosen according to the distribution of the independent variable.

4 Results and discussion

4.1 Preliminary experiment analyses and results

4.1.1 Participants' characteristics

The characteristics of the participants were analyzed based on pre-questionnaires they filled *(**Appendix F** – Preliminary questionnaires analysis**)***.

4.1.1.1 Demographic analysis

The 10 seniors that participated in the experiment included *40%* of females and *60%* males. aged between 67 to 85 *(mean=75, SD=5.55)*. The educational level of 2 participants is Ph.D., 3 have a Master's degree, 2 have a high-school education and 2 have other education.

4.1.1.2 TAP - Technology Adoption Propensity

The degree to which *90%* of the participants, utilized technology was low. Only one of the participants uses technology on a high scale.

20% of the participants noted they have low propensity to adopt technology, while *60%* have medium adoption level. *20%* of the participants have a high propensity to adopt the technology *(mean=3.08, SD=1.4)*. *70%* of participants strongly believe that technology provides increased control and flexibility in life. *70%* of the participants have low confidence in one's ability to quickly and easily learn to use innovative technologies, as well as a sense of being technological. Only *10%* of the participants have high confidence in such ability to quickly learn to use while the remaining *20%* are indifferent about it. *50%* of the participants strongly think that they are being overly dependent on technology, and have a feeling of being enslaved by it, while *50%* are neutral about it. *50%* of the participants have a low belief that technology increases one's chances of being taken advantage of by criminals or firms, *10%* are indifferent about it and *40%* strongly believe it.

4.1.1.3 NARS – Negative attitude toward robots scale analysis

20% of the participants have a low negative attitude towards robots, *20%* have a high negative attitude while *60%* are neutral about it *(mean=13.5, SD=5.56)*. *20%* have highly negative attitudes toward situations which include robots, *30%* are neutral about it while *50%* have a low negative attitude towards such situations. *30%* have highly negative attitudes toward the social influence of robots, *70%* are neutral about it. *30%* have a highly negative attitude toward the concept of robots having emotions, *40%* are indifferent about it while *30%* have a low negative attitude towards it.

4.1.1.4 Analysis of physical activeness

The physical aerobic activity level of the participants varied between underactive to active moderate-vigorous. *10%* of the participants were underactive as defined by the assessment, *40%* were classified as underactive with regular – light activities, *20%* were regularly underactive, *10%* were moderately active and *20%* are active with moderate-vigorous physical activities. Additionally, *10%* noted that they participated in physical activities for strength while *50%* noted they participated in exercises for flexibility.

4.1.2 Subjective measures analysis

4.1.2.1 Evaluations of the robot as an exercise coach analysis

In the evaluation of the robot, *80%* agreed that Nao is a good exercise coach while *20%* disagreed. *70%* agreed that Nao is a good motivator of exercise, that they will recommend Nao for their friends and that they are motivated to exercise with Nao while *20%* strongly disagreed with this statement and *10%* partially agreed. *70%* thought that they will exercise with Nao in the future while *30%* do not think they will. *40%* of the participants preferred to exercise with a robot while *40%* are not in agreement with exercising with a robot while *20%* were simply not fully disposed to the idea.

4.1.2.2 The social attraction analysis

The social attraction of the system was diverse. *40%* thought that Nao could be a friend of them while *30%* disagreed and *30%* were not sure. *20%* thought they could spend a good time with Nao while *50%* disagreed and *30%* were not as convinced that they could. *50%* said that they would want to spend more time with Nao, *20%* didn't want to spend more time and *30%* are indifferent about the idea.

4.1.3 Interviews

4.2 Main experiment analyses and results

4.2.1 Participants' characteristics

The characteristics of the participants were analyzed based on pre-questionnaires they filled ***(*** ***Appendix*** N – Preliminary questionnaires analysis***)***.

4.2.1.1 Demographic analysis

The 32 seniors that participated in the experiment included 18 females and 14 males aged between 70 to 88 *(mean = 77.4, SD = 5.8)*. The educational level of *6.3%* participants was

Ph.D., *15.6%* had a Master's degree, 28.1% had a bachelor's degree, *31.3%* had a high-school education and *18.8%* had other education.

4.2.1.2 TAP - Technology adoption propensity

3.23% of the participants had a low propensity to adopt technology, while *38.71%* had medium adoption level. *58.06%* of the participants had a high propensity to adopt the technology. The mean is *3.54* and the standard deviation is *0.65*. *80.65%* of the participants strongly believed that technology provides increased control and flexibility in life. *41.94%* of the participants had low confidence in one's ability to quickly and easily learn to use innovative technologies, as well as a sense of being technological. *32.26%* of the participants had high confidence in such ability, the remaining *25.81%* are indifferent about it. *58.06%* of the participants strongly thought that they are being overly dependent on technology, and had a feeling of being enslaved by it, while *35.48%* are neutral about it.

4.2.1.3 NARS – Negative attitude toward robots scale analysis

35.48% of the participants had a negative attitude toward situations and interactions with robots, *12.9%* had a high negative attitude while *51.61%* are neutral about it. *22.58%* had highly negative attitudes toward the social influence of robots, *51.61%* had a low attitude and 25.81% were neutral about it. *64.52%* had a highly negative attitude toward the concept of robots having emotions, *9.68%* are indifferent about it while *25.81%* had a low negative attitude towards it.

4.2.2 Evaluation of the training

All the figures for the for subjective evaluation analysis are provided in ***Appendix O*** – *Post-trails questionnaires analysis.*

The subjective evaluation revealed that more than *70%* perceived the system as useful, easy to use, and had a positive attitude toward the system with an intention to use.

4.2.2.1 Perceived usefulness

Most of the participants *(71.9%, mean=2.58, SD=0.73)* indicated through the questionnaire that they perceived the robot as useful for them. Regarding the feedback mode, more of the participants in the audio feedback group *(77.4%)* indicated their willingness to train with the robot at another time compared to participants who experienced audio and visual feedback *(66.7%)*. Regarding the feedback timing, more of the participants in the continuous feedback group *(77.8%)* indicated that their willingness to train with the robot at another time compared to participants who experienced discrete feedback *(64.3%)*. The robot type did not influence the perceived usefulness.

4.2.2.2 Ease of use

4.2.2.2.1 Comfortability

The change in heart rate (= $\frac{HR\ after - HR\ before}{HR\ before}$) *(mean= 0.19, SD=0.268)* was significantly affected by the mode *(F(1,60)=4.101, p=0.047)* and timing *(F(1,60)=7.674, p=0.007)* of the feedback *(**Figure 133**)*. The change in heart rate of participants with continuous feedback *(mean=0.26, SD=0.29)* was higher than participants with discrete feedback *(mean=0.13, SD=0.23)*. Participants with audio feedback *(mean=0.23, SD=0.31)* had higher change in heart rate than participants with combined audio and visual feedback *(mean=0.17, SD=0.23)*.

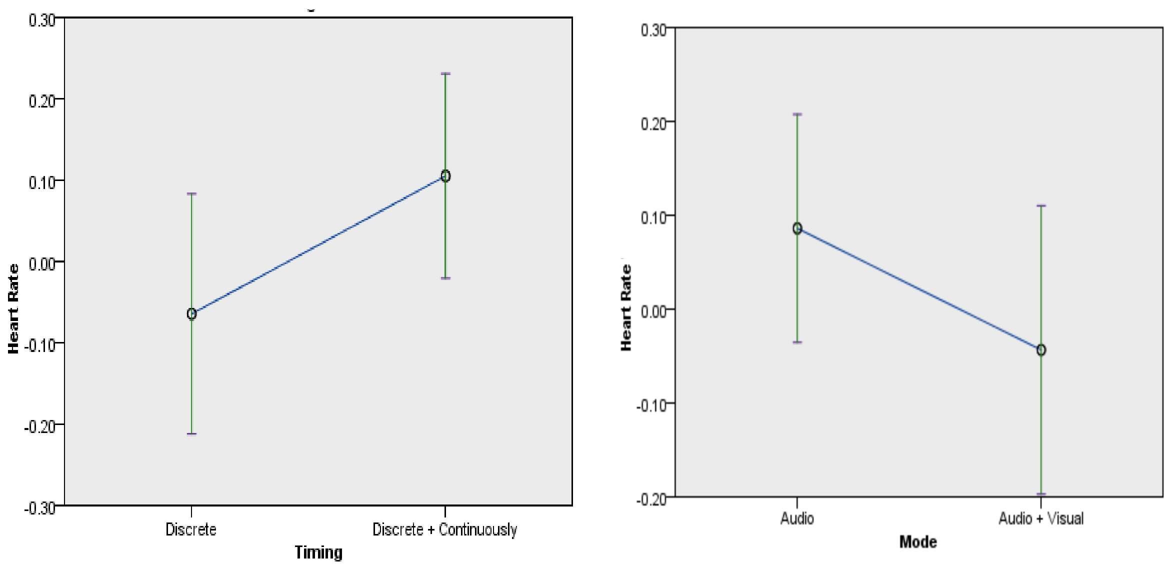


Figure 13: Change in heart rate depending on timing OR mode of feedback

The change in heart rate was not significantly *(F(1,62)=0.318, p=0.575)* affected by the robot type. Participants that exercised with the Poppy robot *(mean=0.18, SD=0.29)* has similar values of change in heart rate as those participants that exercised with the Nao robot *(mean=0.22, SD=0.25)*.

Most of the participants *(92.2%, mean=2.89, SD=0.403)* indicated in the questionnaires that they felt comfortable with the system. Regarding the feedback mode, more of the participants in the audio feedback group *(96.8%)* indicated that they felt comfortable with the system compared to participants who experienced the combined audio and visual feedback *(87.9%)*. Regarding the feedback timing, all the participants in the continuous feedback group indicated that they were comfortable with the system while most of the participants who experienced discrete feedback *(82.1%)* were comfortable. There was a slight difference in the robot type preference regarding the comfortability.

4.2.2.2.2 Understanding

The understanding measured as the reaction time (seconds) of the participants *(mean=3.98, SD=5.635)* was significantly affected by the mode of feedback *(F(1,58)=8.931, p=0.004)* *(***Figure 14***)*. There was a reduction in the reaction time of those using both audio and visual feedback *(mean=2.7, SD=1.845)* compared with participants with only audio feedback

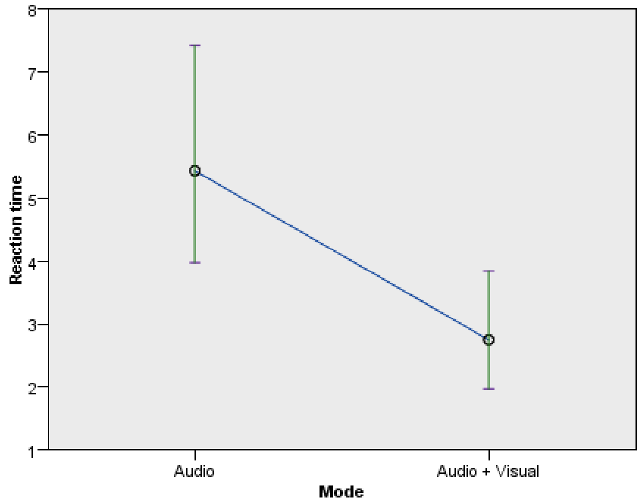


Figure 14: Reaction time by mode of feedback

(mean=5.45, SD=7.82). The reaction time for the participants was not significantly affected by the robot type *(F(1,60)=0.011, p=0.918)* and the timing of feedback *(F(1, 58)=0.704, p=0.405)*. The reaction time of participants that used the Poppy robot *(mean=3.9, SD=6.05)* was shorter than participants who used the Nao robot *(mean=4.06, SD=5.23)*. Additionally, a reduction in reaction time was observed in participants who experienced continuous feedback *(mean=3.53, SD=5.165)* as compared to participants with discrete feedback *(mean=4.54, SD=6.21)*.

The number of incorrect responses *(mean=0.27 , SD=0.672)* was not significantly affected by the robot type *(F(1,62)=2.691, p=0.106)*, timing *(F(1,60)=0.402, p=0.528)* and mode *(F(1,60)=0.617, p=0.435)* of feedback. The number of incorrect responses of participants that used the Poppy robot *(mean=0.156, SD=0.45)* was smaller than participants who used the Nao robot *(mean=0.375, SD=0.83)*. Audio and visual feedback *(mean=0.18, SD=0.46)* decreased the number of incorrect responses in comparison to participants with only audio feedback *(mean=0.35, SD=0.84)*. In addition, time for incorrect responses for participants with continuous feedback *(mean=0.305, SD=0.786)* was similar to the time for incorrect responses for participants with discrete feedback *(mean=0.214, SD=0.5)*.

The number of questions from participants to clarify certain aspects of the interaction *(mean=0.25 , SD=0.504)* was not significantly affected by the robot type *(F(1,62)=0.003,* *p=0.959)*, timing *(F(1,60)=0.033, p=0.856)* or mode *(F(1,60)=0.114, p=0.736)* of feedback. The number of clarification questions for participants that used the Poppy robot *(mean=0.22, SD=0.49)* was slightly lower than for the participants who used the Nao robot *(mean=0.28, SD=0.522)*. Participants who experienced audio feedback *(mean=0.19, SD=0.477)* asked less questions than participants that experienced the combined audio and visual feedback *(mean=0.3, SD=0.529)*. Additionally, participants with discrete feedback *(mean=0.214, SD=0.498)* asked slightly less questions than participants with continuous feedback *(mean=0.278, SD=0.51)*.

The persistence to complete the exercises of the participants *(mean=0.4, SD=0.453)* was significantly affected by the timing of feedback *(F(1,60)=12.822, p=0.001)(**Figure 15**)*. The participants' persistence to complete the exercises by participants who experienced continuous feedback *(mean=0.57, SD=0.45)* was higher than participants with discrete feedback *(mean=0.18, SD=0.37)*. The persistence was not significantly affected by robot type *(F(1,62)=0.677, p=0.414)* and mode of feedback *(F(1, 60)=2.697, p=0.106)*. Audio and visual feedback *(mean=0.5, SD=0.47)* influence for higher persistence of the participants than audio feedback (*mean=0.3, SD=0.41)*. The persistence of participants with the Poppy robot *(mean=0.35, SD=0.45)* was lower than participants who used the Nao robot *(mean=0.45,*

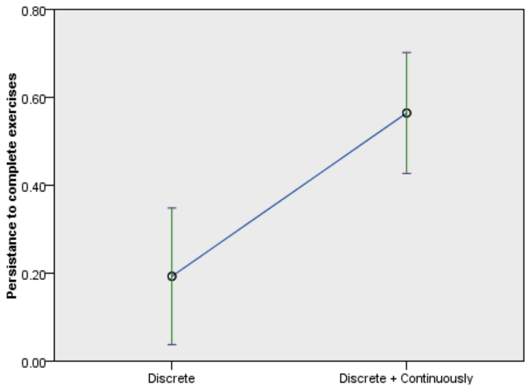


Figure 15: Persistence to complete the exercises by timing of feedback

SD=0.46).

Most of the participants *(92.2%, mean=2.88, SD=0.454)* indicated in the questionnaire that they understood the system well. Regarding the feedback mode, more of the participants in the audio feedback group *(96.8%)* indicated that they understood the system better compared to participants who experienced the combined audio and visual feedback *(88%)*. Regarding the feedback timing, all the participants in the continuous feedback group indicated their comfortability while most of the participants who experienced discrete feedback *(82.1%)*

indicated comfortability. There was a slight difference in the robot type preference regarding the comfortability.

4.2.2.2.3 Effort

Most participants noted that the activity did not require from them effort *(73.4%, mean=1.42, SD=0.752)* as seen in their questionnaire's responses. The participants in the audio and visual feedback group *(78.8%)* perceived less effort compared to participants who experienced only the audio feedback *(67.7%)*. Regarding the timing of feedback, the participants in the continuous feedback group *(80.6%)* perceived less effort compared to participants who experienced discrete feedback *(64.3%)*. There was a slight difference in the robot type preference regarding the effort, *75%* preferred Poppy while *71.9%* preferred Nao.

4.2.2.3 Attitude

4.2.2.3.1 Engagement

Engagement, measured as the ratio of the participants with "no eye contact" to trial total time *(mean=0.038, SD=0.067)* was significantly affected by the robot type *(F(1,61)=35.257, p<0.001)* ***(Figure 17)***, timing *(F(1,60)=23.157, p<0.001)* and mode *(F(1,60)=4.622, p=0.036)* of feedback ***(Figure 16)***. The ratio of the participants "no eye contact" to trial total time, for participants that used the Poppy robot *(mean=0.029, SD=0.0492)* was lower than participants who used the Nao robot *(mean=0.463, SD=0.08)*. The ratio for participants who experienced audio and visual feedback *(mean=0.036, SD=0.06)* was lower than participants with audio feedback *(mean=0.403, SD=0.0763)*. The ratio for participants with continuous feedback *(mean=0.03, SD=0.048)* was smaller than participants with discrete feedback *(mean=0.0483, SD=0.865)*.

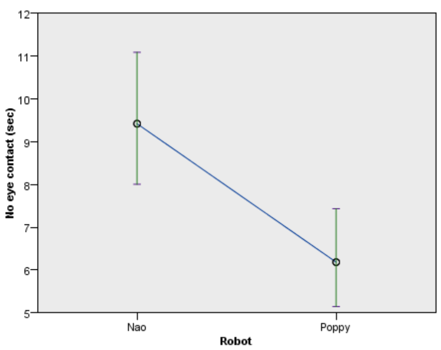


Figure 17: No Eye contact by type of robot

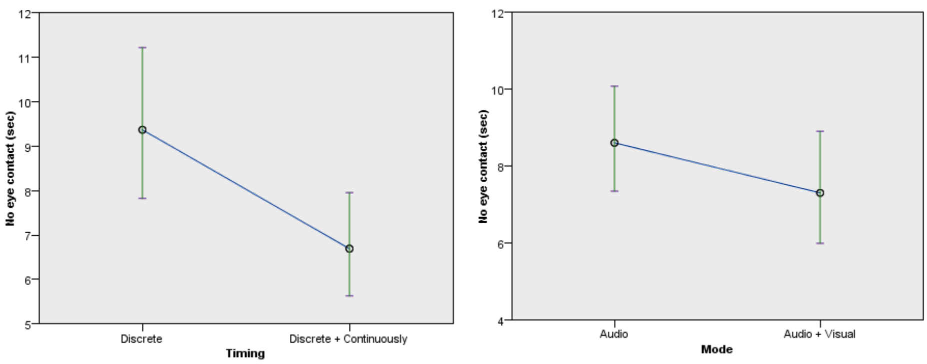


Figure 16: No eye contact by timing OR mode of feedback

Majority of the users indicated in the questionnaires that they were engaged in the activity throughout the session *(96.9%, mean= 2.94, SD=0.351)*. Regarding the feedback mode, all the participants in the audio and visual feedback group indicated they were engaged with the system while most of the participants who experienced audio feedback *(93.5%)* noted they were engaged with the system. The timing of the feedback and the robot type only slightly influenced the engagement.

The engagement was significantly affected by the users perceived ease of use *(comfortability $F(1,57)=17.603$, $p<0.001$, understanding ($F(1,57)=153.335$, $p<0.001$))* and perceived usefulness *($F(2,60)=7.069$, $p=0.002$)*.

4.2.2.3.2 Trust

Most of the participants *(mean=2.77, SD=0.527)* indicated in the questionnaire that they trusted the robot. Regarding the feedback timing, most participants in the continuous feedback group *(88.9%)* indicated their trust compared to participants who experienced discrete feedback *(71.4%)*. Regarding the robot type, more participants who trained with Poppy *(84.4%)* trust the robot compared to participants who trained with the Nao robot *(78.1%)*. There was a slight difference in the feedback mode preference regarding trust.

Based on the subjective assessment, the trust was significantly affected by the understanding of the system *($F(1,56)=9.67$, $p=0.003$)* and by perceived usefulness *($F(2,60)=4.725$, $p=0.012$)*.

4.2.2.3.3 Satisfaction

Most of the participants *(85.9%, mean=2.8, SD=0.54)* indicated in the questionnaire that they were satisfied by the robot's performance (with remaining 6/64 unsatisfied and 5/64 were neutral). Regarding the feedback mode, more of the participants in the audio feedback group *(90.3%)* indicated their satisfaction from the robot compared to participants who experienced audio and visual feedback *(81.8%)*. Regarding the feedback timing, more of the participants in the continuous feedback group *(94.4%)* indicated that their willingness to train with the robot at another time compared to participants who experienced discrete feedback *(75%)*. The satisfaction of users who interacted with the Poppy robot *(90.6%)* was higher than users who interacted with the Nao robot *(81.3%)*.

Based on the subjective assessment, the satisfaction of the users was significantly affected by the users' perceived usefulness *(comfortability $F(2,60)=4.911$, $p=0.11$)* and by perceived usefulness *($F(2,60)=4.911$, $p=0.011$)*.

4.2.2.3.4 Adherence to training

This was assessed by the success rate of the participants *(73%)* which was significantly affected by the timing of feedback *(F(1,377)=4.485, p=0.035)(**Figure 18**)*. 63.9% of the participants succeeded better with discrete audio feedback while with continuous feedback the success rate increased to *80%*. The success rate of the participants was almost significantly affected by the robot type *(F(1,379)=3.694, p=0.055). 76.6%* of the participants succeeded better with the Poppy robot as compared to the session with the Nao robot (which resulted in *69%* success rate). The success rate was not significantly affected by the feedback mode *(F(1,377)=2.032, p=0.155)*. However, with audio and visual feedback the success rate reached *78.8%* while the success rate decreased to *67%* with only audio feedback.

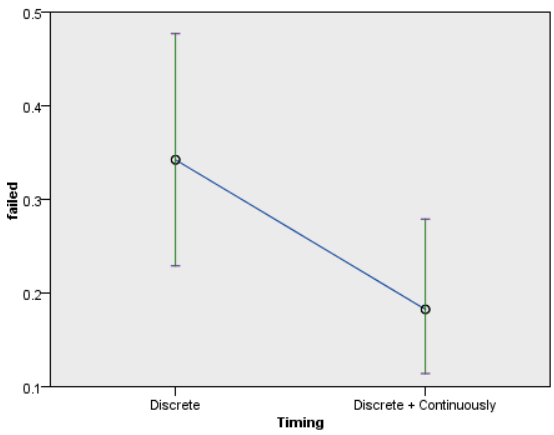


Figure 18: 'Did not succeed' vs. timing of feedback

4.2.2.3.5 Enjoyment

Most of the participants *(81.3%, mean=2.8, SD=0.443)* indicated in the questionnaire that they enjoyed the activity. More of the participants in the continuous feedback group *(94.4%)* indicated their enjoyment compared to participants who experienced discrete feedback *(75%)*. There was a slight difference in the robot type (Poppy was preferable) with respect to enjoyment. The influence of the feedback modes was almost equal regarding enjoyment during the interaction, but audio and visual feedback was preferred *(81.8%)* over only audio feedback *(80.6%)*.

The enjoyment from the system was significantly affected by the users' perceived usefulness *(F(2, 60)=8.106, p=0.001)*. The results revealed that *97.8%* of the participants would be willing to train with the robot in the future because it had value for them, and they enjoyed the activity.

4.2.2.4 Intention to use

Most of the participants *(76.6%, mean=2.69, SD=0.614)* indicated in the questionnaires their intention to use the system. More of the participants in the audio feedback group *(80.6%)*

indicated their intention to use the system compared to participants who experienced audio and visual feedback *(72.7%)*. Regarding the feedback timing, more of the participants in the continuous feedback group *(80.6%)* indicated it than participants who experienced discrete feedback *(71.4%)*. Regarding robot type, more of participants with Poppy robot *(81.3%),* indicate their behavioral intention to use compared to participants who experienced Nao robot *(71.9%)*.

The behavioral intention to use the robot was significantly affected by the users' enjoyment *(F(2,53)=7.421, p=0.001)*. Analysis of results revealed that *92.3%* of the participants who enjoyed the activity would like to exercise with the robot in the future.

4.2.3 Overall assessment of the participants' interaction

71.88% of the users understood both robots (Poppy and Nao), while only 1 participant *(3.13%)* did not understand the robots. *6.25%* understood Nao better and *18.75%* understood Poppy better.

43.75% of the users would choose to use both robots while *9.38%* would not choose any robot. *31.25%* preferred to use Nao and *15.63%* preferred Poppy.

62.5% of the users prefer that the system will provide continuous feedback while 37.5% preferred discrete feedback. *72.2%* of the users that experienced continuous feedback preferred the system to provide continuous feedback while only *50%* of the users that experienced discrete feedback preferred continuous feedback.

90.63% of the users would like to train with the system while *9.38%* would not.

4.3 Summary

The results revealed that the system fulfills the aim of motivating older adults to be more engaged in physical exercises. *90.64%* of the users indicated that they would like to train with the robotic coach in the future. Most of the users perceived the system as very useful *(71.9%)* and easy to use *(85.9%)*. Most of them also had a positive attitude towards the system *(86.3%)* and had the intention to use it *(76.6%)*.

The summary of the objective measures are as follows:

- Continuous feedback significantly increased positive attitude, better understanding, and engagement. It also reduced the reaction time. However, the comfortability of the users with discrete feedback was significantly better than with continuous feedback.
- The Poppy robot significantly increased the positive attitude of the participants compared to the Nao robot. Poppy engaged the users significantly more than the Nao robot. Additionally, Poppy increased the participants' adherence to training almost significantly. Poppy also increased the understanding of the system.
- Audio and visual feedback was significant as the preferred feedback mode with regards to engagement, comfortability, and ease of use of the system. In addition, the persistence and adherence to training with audio and visual feedback was higher than with only audio feedback.

4.4 Discussion

The system can provide a verbal and visual form of feedback at different timings according to the users' performance. It commands the participants if they complete the exercises or not. It can also count aloud as the participant undergoes each step of the exercises. Additionally, it can give visual feedback which includes LED lights in the Nao robot and facial expression in the Poppy robot's' screen. In cases where the user does not complete the exercise, the system gives corrective feedback and asks if the user wants to redo the exercise.

4.4.1 Influence of the developed feedback on older adults' performance

The feedback that was given by the system helped the users understand the gap between their intended and actual performance as described in the literature. They knew through the feedback given if they did the exercises correctly and as expected.

Adding visual feedback, especially in the system that included the Poppy robot, helped the users to understand better the feedback and the system. As described in the literature, part of the older adults tends to be hearing impaired; therefore, a system that includes visual feedback helps the older adults to understand the system even if they have hearing limitations and as a result don't hear the audio feedback.

In the session with the continuous feedback that includes counting, it was shown that it helped part of the users keep track of the number of right steps and repetitions they had made. It was observed from the videos that some of the participants with discrete feedback had a gap in their performance in the exercise. Some of the participants were unsure if they made the correct movement and they were not confident about it. This correlates with the observations the existing literature revealed. However, some noted that they preferred the system without counting feedback. We assume that for those people, the counting along exercising it was excessive feedback as observed in the literature. Continuous feedback provides better understanding, enjoyment, and trust of the system by the users.

4.4.2 Influence of the developed system on users' perception and interaction

Most of the users perceived the system as very useful, providing good motivation for future development. The users believed that this system can be useful for them. The importance of physical activity is well known for older adults and we observed that such a system can motivate and help the users to be more active.

The change in heart rate is a common measure for evaluating comfortability in Human-Robot-Interaction. However, in the current experiment since the exercises influence the heart rate due to users' effort and their level of physical activity its analysis is limited. This could explain the reason why the change in heart rate was not significantly affected by the type of robot.

The users indicated that the system was easy to use. This seems to show that the visual feedback in addition to the audio feedback helped the users better understand the system and what they are supposed to do better. It reduced their reaction time and increased the persistence of training.

The attitude of the users for the system is positive, the users are engaged by the system. They keep eye contact most of the time in the system. This confirms the literature which notes that users attitude is influenced by the type of feedback (Mirnig et al., 2011). It is also noteworthy that continuous feedback engaged the participants more than discrete feedback. The Poppy robot also engaged the users more than Nao robot. We think that the facial expression on the screen of Poppy has some influence on the positive perception of the users as seen in the literature (Lang et al., 2009). Such facial expressions seem to make the robot's behavior better understandable (Van Breemen, 2004). In the research of Mirnig et al., 2014, it was also noted that providing some facial expressions as feedback made the users consider the robot as more attractive (Mirnig et al., 2014). Another reason might be the more technical look of the Poppy versus the humanoid toy looking of the Nao robot. Continuous feedback was also observed to improve the flow of interaction.

Regarding the trust of the users in the system with Poppy, we think it might be because of the shape of the poppy which includes observable robots and wires, that gives the users that it not a toy while the Nao robot is more toy shaped. In addition, the continuous feedback is preferable because it helps the users to receive indication through the exercise and not only at the end, which increases the trust in the system.

Continuous feedback also improves the success rate and the enjoyment from the system.

5 Conclusions and recommendations

5.1 Conclusions

The system fulfills the aim of motivating older adults to engage more in physical exercises. In the experiment, the subjects engaged in the physical exercises with the aid of the robotic system for 15 minutes in total. The participants used the system without problems, they understood what they needed to do even though it was the first time they used the system or anything similar to it. It improved their performance during the session. The participants indicated they are eager to train with a robotic coach.

The exercises and the demonstrations were good and clear. The combination of the instructions (given by human voice) and physically demonstration enabled the participants to understand what they ought to do and how to do the exercise. This multimodal guide (visual and audial) considered some of the perceptual limitations of the older adults such as a decline in audial or visual acuity. It was therefore helpful for participants with hearing loss.

Most of the participants evaluated the robots as a good exercising coach and responded that they enjoyed the interaction with the robot which they considered as a form of mutual training for them and the robot coach.

Most of the participants were comfortable with the pace of the exercises. It is therefore recommended that the pace should remain as it is.

The feedback was important to the participants, it made the interaction more fluent and nicer. However, it is recommended that the feedback should be more accurate and informative.

In order to increase the variety in the sessions, it is also recommended that additional strength and stability exercises should be added to the system.

The participants' preference for Poppy seems to suggest that the embodiment and movement of the robot influences users' attitude, perception, and interaction with the robot.

The mode and timing of feedback influence the quality of users' interaction with the robotic coach in physical training.

We recommend the system for the personal use of older adults. The recommended use is at least 3 times a week.

5.2 Limitations

Existing studies recommend that feedback should be adequate and informative. The information content of the corrective feedback was minimal to avoid overloading the user with information since literature confirms that it increases the cognitive workload of the user and decreases performance. The information content explored in this study was therefore just in relation to the number of times the user should perform the exercise and at the end of the exercise (the robot congrats the user of asking him to redo the exercise).

In this research, there are several exceptions that our design could not overcome. These include:

- Variability in the participants – there is high variability in the personality differences of older adults, and this has an impact regarding their preferences.
- Novelty effect – it was the first time that the users interacted with a robotic coach and their assessments may change over an extended period of interaction.
- More assessments with the gaze monitoring system – this could be taken to improve the accuracy of the gaze duration but was not taken in this study in order to avoid burdening the participants.
- Cognitive, hearing and vision condition of the participants – a standard assessment of these measures were not taken. It is noteworthy that cognitive, hearing or visual impairments can affect the interaction of the users with the robot and influence the results. This could be considered for future studies.

5.3 Recommendations

There are several suggestions for future research to create a more interactive, effective and enjoyable physical exercise robotic system for older adults.

- Improve the informational content of the feedback as recommended, more feedback content options should be explored to improve the effectiveness, efficiency, and enjoyment of the system.
- Improvement of the system should include more accurate and informative type of feedback and new interactions and responses of the robot. Background music should also be added.
- Adding difficulty levels for the users that will be adaptive according to the users' performance and level.

- Additional exercises should be added to the system in order to increase the variety in the sessions.
- Long term study (several weeks/months) to examine satisfaction and usage over time. This will reduce the novelty effect users experience in the first meeting a robot and will provide a better assessment of the system.
- More participants should be mended in further experiments in order to assess a wide variability of preferences.
- Evaluation of different older adults age groups and backgrounds.
- Incorporating an emotion recognition learning algorithm in the system has the potential to improve the system feedback. Such a learning algorithm for emotion recognition can enable the system to classify the users' emotion (bored, exhausted, fascinated, happy, etc.) and thus provide better feedback with recommendations for improved performance (more challenging exercises, games, etc.).
- Incorporating an imitation learning algorithm as a mirror for the movements of the users can provide a real-time assessment of the users' performance. It can help the users see the kind of movements they are making and guide them in improving those movements if they are making a wrong movement. This has the potential to improve the feedback because it will show the users what was wrong in their movements.
- Adding a voice recognition algorithm has the potential to improve the communication and the interaction between the robot and the user.
- Using a different depth camera other than the Kinect has the potential to enable the system to better detect and monitor users that are sitting. This can provide more diversity of use because some older adults may not be able to stand for long or may prefer a sitting posture for some exercises while some may be on wheelchairs.
- Using the system in front of a group of users instead of as an individual trainer. This can lead to higher motivation through the social interaction effect.

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7 Appendices

7.1 Preliminary study

7.1.1 Appendix A - BGU ethical committee

Name of Research Project: Developing a Physical Robotics System for Older Adults

Research Protocol:

The research protocol should contain a full description of the project stages that pertain to the experimental method and all interaction with the human subjects. If the project contains a series of experiments, describe the variations; also include description of type and number of subjects and subject recruitment method. If this type of protocol is one commonly used and/or if a similar protocol and methods have been used and published in the literature, please add references indicating so. Please do not submit the complete project proposal that was submitted to the funding agency, the protocol should be maximum 2 pages long.

Purpose:

The aim of the experiment is to examine the effectiveness of the system in motivating seniors to do physical activity.

Subjects:

Participants will be seniors (older than 60) in good health. Participation in the research will be on a voluntary basis and will require signing an informed consent for approval. The recruitment will be done by publishing advertisement (via university, social networks etc.) and invitation to contact the experimenters.

Procedure:

At the recruitment stage, participants will be asked regarding their health condition. Participants whose health will not be good enough will not be able to participate in the experiment.

In the beginning, the subjects will sign a consent form and fill a preliminary questionnaire which will include details about their current health condition. Then, they will be asked to fill few preliminary questionnaires (including demographic details, physical fitness level (an online questionnaire), TAP (Ratchford & Barnhart, 2012) and NARS (Taylor Katz & Halpern, 2013). In addition, during the experiment, the participant will be able to stop the experiment by raising his hand or saying they want to quit. In this case, the eperiementer will immediately stop the eperiement and approach the participant for help and will ask him to sit down.

Before experimenting the use of the system on the subjects, the researcher will explain them about the system, how it works and about the procedure of the experiment. First, the robot will introduce itself to the participants and will provide them a brief explanation of the training.

During the experiment, the robot will demonstrate the subjects some low-intnsity level physical activity exercise (without aerobic activity) and the subjects will need to imitate the robot and repeat the exercises. The practice in front of the robot has no effort beyond the minimum effort in terms of cardiovascular endurance. The The excercises will be of low-intensity level like standing in the place and raising his hands to shoulders level, uses a chair as support and raises his legs to the side. The duration of each exercise will be up to 1 minutes. The total time of the whole session will be maximum 15 minutes.

The robot will provide the subjects verbal feedback according to their execution.

During the experiment, there will be no physical contact between the subject and the robot. Therefore, no risk will exist during the experiment.

At the end of the training, subjective assessments will be conducted using questionnaires and interviews. The subjective assessment tools will be used to evaluate and identify dimensions of user acceptance (or unacceptance of the technology), satisfaction and trust.

Measurements:

At the end of each scenario, subjective assessments will be conducted using questionnaires.

References:

- Ratchford, M., & Barnhart, M. (2012). Development and validation of the technology adoption propensity (TAP) index. Journal of Business Research, 65(8), 1209–1215.
- Taylor, P., Katz, J. E., & Halpern, D. (2013). Behaviour & Information Technology Attitudes towards robots suitability for various jobs as affected robot appearance, (July 2014), 37–41.
- physical fitness level questionnaire - http://depts.washington.edu/hprc/wp-content/uploads/rapa_03_06.pdf

I. General

Name of Research Project: Developing a Physical Robotics System for Older Adults

To which agency is the proposal being submitted (or has been submitted): CDI

Principal Investigator/s (or academic supervisor/s):

Name: **Yael Edan**	**Name**: **Vardit Fleischmann**
Department: IEM	**Department:** IEM
Academic position: Prof	**Academic position:**
University Telephone: 08-6472232	**University Telephone**:
Mobile Phone: 3683931-052	**Mobile Phone:**
University Email: yael@bgu.ac.il	**University Email:** varditf@gmail.com
Other Email:	**Other Email:**

Name(s) of those conducting the research (if different from above):

Name: Omri Sarig	**Name**: -

Department: IEM	**Department:** -
Academic position: Student	**Academic position:** -
University Telephone: -	**University Telephone**: -
Mobile Phone: 054-7418881	**Mobile Phone:** -
Email: sarigomr@post.bgu.ac.il	**Email:** -

II. Consent to Participate

1. Are the subjects able to legally consent to participate in the research? ☒Yes / ☐ No

   If you answered 'No' to question 1, complete section IIb

2. Will the subjects be asked to sign a consent form? ☒Yes / ☐ No

   If you answered 'No' to question 2, explain here**:**

IIb: Subjects who cannot legally consent (minors, mentally incapacitated, etc.):

3. Will the subject's legal guardian be asked to sign a consent form? ☐Yes / ☐ No

   If you answered 'No', to question 3, please explain here:

4. Will the subject be asked to give oral consent? ☐Yes / ☐ No

5. Are the instructions appropriate to the subjects' level of understanding? ☐Yes / ☐ No

Comments:

6. If informed consent forms will be signed, how will the informed consent forms be stored to ensure confidentiality? All signed forms will be saved in a locked cabinet.

III. Discomfort:

7. Will the participants be subjected to physical discomfort? ☐Yes / ☒ No

8. Will the participants be subjected to psychological discomfort?: ☐Yes / ☒ No

If you answered 'Yes' to question 7 or 8, add here a detailed explanation of the circumstances:

IV. Deception

9. Does the research involve deceiving the subjects? ☐Yes / ☒ No

10. Is the decision on the part of the subject to participate in the study based on deception? (For example, if they are informed of their participation only after the event.) ☐Yes / ☒ No

    If you answered 'Yes' to question 9 or 10, add here a detailed explanation why deception is necessary:

V. Feedback to the Subject

Note: Although feedback to the subject is recommended for *all* studies, it is required for studies that involve discomfort or deception. Feedback entails providing the subject, upon completion of the experiment, explanation of the experiment and its aims.

11. Will the subjects be provided with post-experiment oral feedback? ☒Yes / ☐ No

12. Will the subjects be provided with post-experiment written feedback? ☒Yes / ☐ No

    If you answered 'No' to both questions 11 and 12, explain here:

VI. Compensation for Participation

13. Will the subjects receive compensation for participation? ☐Yes / ☒ No

    Detail here the type and amount of compensation:

    If you answered 'No' to question 13, explain the basis for participation: It will be informed to the subjects that the experiment is performed volunteerly.

VII. Privacy:

14. Will audio and/or visual recordings be made of the subjects? ☒Yes / ☐ No

    a. If yes, are they informed of this fact in the informed consent form? ☒Yes / ☐ No

15. Will the data collected (apart from the informed consent form) contain identifying details about the subjects? ☒Yes / ☐ No

a. If the data contains identifying details, please answer here: (1) What steps will you take to ensure the confidentiality of the information? (2) How will the data be stored? (3) What will be done with identifying information or recordings of the subjects at the end of the research? The only data which will contain identifying details (except from the consent form) will be the audio and video files (of the participants while using the system). All data files will be encoded by password and saved in the researchers' PCs.

VIII. Withdrawal from the Study:

16. Will subjects be informed that they may withdraw from the study at any time? ☒Yes / ☐ No

17. Will the subjects' compensation for participation be affected if they withdraw from the study before its completion? ☐Yes / ☒ No

    a. If yes, are they informed of this fact in the informed consent form? ☐Yes / ☐ No

IX. Research Equipment

18. Does the research entail the use of equipment other than standard equipment, such as computers, video recording equipment? ☒Yes / ☐ No

19. If yes, does the equipment being used meet safety standard for use with human subjects? ☒Yes / ☐ No

Please specify which standards (include documentation where appropriate):

The robotic system will include Nao's robot version 5 or 6(https://www.ald.softbankrobotics.com/en/robots/nao), (which complies with the IEC/EN 60950 safety standard), and a Kinect camera(which complies with the ISO Standard 16331-1). The Kinect will enable to analyze the movements of the subject and Nao will instruct and demonstrate the exercises as their personal coach. In addition, we will use a simulator that will present on a screen and will include a demonstration of Nao's robot.

Signatories:

Signature: ______________ **Date**:

Name: Omri Sarig **Position**: Student

Signature: ______________ **Date**: 09/04/18

Name: Yael Edan **Position**: Professor

טופס הסבר לנבדק

טופס הסכמת הנבדק להשתתפות בניסוי

נושא המחקר: פיתוח מערכת רובוטית לאימון מבוגרים

*גוף השאלון מנוסח בלשון זכר מטעמי נוחות והינו מכוון לשני המינים

נבדק יקר,

בבקשה קרא את דף ההסבר באשר לניסוי. במידה ויש שאלות, נשמח לענות.
בבקשה וודא כי הנך מבין היטב את שלבי המחקר.

במהלך הניסוי תתבקש לבצע אימון גופני באמצעות רובוט וירטואלי שיהיה המאמן האישי שלך.

המחקר הנוכחי נערך באוניברסיטת בן-גוריון ועוסק באימון גופני באמצעות רובוט .

במסגרת המחקר תבצע אימון של 10-15 דקות בהדרכתו של הרובוט הוירטואלי. הרובוט הוירטואלי ידגים וינחה אותך איזה תרגיל לבצע כל פעם.

חשוב לציין כי הניסוי הוא אנונימי וכי לא מתבצעת שמירה של הפרטים המזהים של הנבדקים. כל נבדק מקבל מספר נבדק. המספר מופרד מפרטי הנבדק וכל השאלונים שימולאו יימסרו לחוקרת הראשית הממונה על המחקר וישמרו באחריותה.

אם מכל סיבה שהיא הינך חש שלא בנוח, בבקשה עצור את הניסוי באמצעות הרמת יד או בקשה מילולית ועורכת הניסויים תיגש אליך באופן מיידי. בכל עת ובכל שלב תוכל, אם תרצה, להפסיק את השתתפותך במחקר. במידה ורצונך כי הניסוי ייפסק, תשוחרר מהניסוי.

אני החתום מטה *:

שם פרטי ומשפחה:	ת.ז.
חתימה:	טלפון:

א. מצהיר/ה בזה כי אני מסכים/ה להשתתף בניסוי, כמפורט במסמך המפרט את חלקי הניסוי.

ב. מצהיר/ה בזה כי אני במצב בריאותי תקין המאפשר לי לבצע פעילות גופנית. אנא סמן וי ליד הפעילויות שאתה מסוגל לעשות

- □ אני מסוגל לעלות 5 מדרגות ברצף בלי הפסקה
- □ אני מסוגל לבצע הליכה של 15 דקות ברציפות
- □ אני מסוגל להרים ידיים / רגליים
- □ אני מסוגל לשבת על כיסא

ג. מצהיר/ה שהוסברו לי בפירוט כל חלקי הניסויי והסכמתי ליטול בו חלק לאחר שנענו כל שאלותיי לגבי כל אחד מחלקי הניסוי.

ד. מצהיר/ה בזה כי הוסבר לי על-ידי החוקרת: _______________

- □ כי אני חופשי לבחור שלא להשתתף בניסוי וכי אני חופשי להפסיק בכל עת את השתתפותי בניסוי מכל סיבה שהיא.
- □ במידה ואני חש ברע או באי נוחות במהלך הניסוי חובה עלי לדווח לנסיין על מנת להפסיק את הניסוי.
- □ מובטח שזהותי האישית תשמר סודית על-ידי כל העוסקים והמעורבים במחקר ולא תפורסם בכל פרסום כולל בפרסומים מדעיים, אלא אם כן אאשר זאת בחתימתי.
- □ מובטחת לי נכונות לענות לשאלות שיועלו על-ידי.

ייתכן ובמהלך הניסוי החוקרים יצלמו תמונות וסרטונים לצורכי מחקר בלבד.

במידה ואתה מאשר\ת זאת חתום כאן : _______________

במידה ואת\ה מסכימים שתמונתכם תופיע בפרסומים שונים שיוצגו לציבור אנא ציינו:

☐ אני מסכים שתמונתי תופיע בפרסומים שונים

☐ איני מעוניין שתמונתי תופיע

הצהרה זו הנה סודית ואינה ניתנת להעברה או שימוש לצורך שום דבר או גורם אחר פרט לצורכי * מחקר זה.

תאריך _______________ חתימת מעביר הניסוי _______________

חתימת המשתתף/ת בניסוי _______________

אנו מודים לך על השתתפותך במחקר.

לפרטים נוספים ניתן לפנות ל:

פרופ' יעל אידן בטלפון 08-6472232 או בדוא"ל yael@bgu.ac.il

עמרי שריג בטלפון 054-7418881 או בדוא"ל sarigomr@post.bgu.ac.il

~~~~~~

This section is to be filled out by a member of the Human Subjects Research Committee only

Decision of the Committee:

Note: The decision of this committee pertains only to ethical considerations involved in the conduct of the research.

Request Number:

Request Sub-Number:

Title of Research Project:

Principal Investigator/s:

Approval for research: ☐ Granted / ☐ Denied

Comments to the researcher in the event that application has been denied:

____

Signature of committee:

Name: ______________________

Signature: ______________________ **Date**:
~~~~~~

7.1.2 Appendix B – Pre-questionnaires

7.1.2.1 NARS questionnaire

Negative Attitudes toward Robots Scale (NARS)

Subscale	Item
S1: Negative Attitude toward Situations of Interaction with Robots	I would feel uneasy if I was given a job where I had to use robots. The word "robot" means nothing to me. I would feel nervous operating a robot in front of other people. I would hate the idea that robots or artificial intelligences were making judgments about things. I would feel very nervous just standing in front of a robot. I would feel paranoid talking with a robot.
S2: Negative Attitude toward Social Influence of Robots	I would feel uneasy if robots really had emotions. Something bad might happen if robots developed into living beings. I feel that if I depend on robots too much, something bad might happen. I am concerned that robots would be a bad influence on children. I feel that in the future society will be dominated by robots.
S3: Negative Attitude toward Emotions in Interaction with Robots	I would feel relaxed talking with robots.* If robots had emotions, I would be able to make friends with them.* I feel comforted being with robots that have emotions.*

(*Reverse Item)

7.1.2.2 TAP questionnaire

Table 1
EFA pattern matrix.

Item	Component 1	2	3	4
1. Technology gives me more control over my daily life.	.85			
2. Technology helps me make necessary changes in my life.	.85			
3. Technology allows me to more easily do the things I want to do at times when I want to do them.	.84			
4. New technologies make my life easier.	.81			
5. I can figure out new high-tech products and services without help from others.		.94		
6. I seem to have fewer problems than other people in making technology work.		.84		
7. Other people come to me for advice on new technologies.		.79		
8. I enjoy figuring out how to use new technologies.		.77		
9. Technology controls my life more than I control technology.			.85	
10. I feel like I am overly dependent on technology.			.84	
11. The more I use a new technology, the more I become a slave to it.			.78	
12. I must be careful when using technologies because criminals may use the technology to target me.				.86
13. New technology makes it too easy for companies and other people to invade my privacy.				.83
14. I think high-tech companies convince us that we need things that we don't really need.				.69
Cronbach's α	.87	.87	.78	.73

Note: all loadings less than .30 are not shown.

7.1.2.3 Technology used questionnaire

1. Use a GPS system:
2. Use "self check-out" at stores:
3. Deposit over $100 at an ATM:
4. Video calling such as Skype:
5. Voice over IP calling:
6. Online data backup services:
7. Buy an item at a vending machine or pay a parking meter using your cell phone:

7.1.2.4 Physical fitness level questionnaire

How physically activity are you? (Ref to http://depts.washington.edu/hprc/wp-content/uploads/rapa_03_06.pdf - Mendeley stopped work)

7.1.3 Appendix D – Post-questionnaires

TABLE VII: Evaluations of the robot as an exercise coach

Question	yes	not much	no
Nao is a good exercise coach	17	1	0
Nao is a good motivator of exercise	18	0	0
Recommend Nao to my friends	16	0	2
Exercise with Nao in the future	18	0	0
Motivated to exercise with Nao	18	0	0
I prefer to exercise with robot	18	0	0

TABLE VIII: The social attraction

Question	yes	maybe	no
Nao could be a friend of mine.	18	0	0
I could spend a good time with Nao.	18	0	0
I want to spend more time with Nao	17	1	0

(Guneysu & Arnrich, 2017)

7.1.4 Appendix E – Post interview

Describe your experience while interacting with the system?

Was it good?

What part of it did you enjoy the most?

What would you like to improve?

What do you feel about the system feedback?

Are you interested in this system?

Do you think that using such a system, over time, can make you do more exercise?

What do feel is the difference between training by a robot and training by a person? Pros & Cons

Which amount would you pay for the system?

What would you like to get from your system in addition?

Presenting NAO

What did you think of the robot?

What amount would you pay for the system with the robot?

7.1.5 Appendix F – Preliminary questionnaires analysis

7.1.5.1 Demographic

Table 8: Demographic participants

Number Asterisked	Age	Gender	Native Language
1	71	Male	English
2	78	Male	English
4	67	Female	English
5	67	Male	Hebrew
6	75	Female	Arabic
7	80	Male	Arabic
8	85	Female	Hebrew
9	80	Male	Hebrew
10	74	Female	English
11	73	Male	English

Table 9: Participants by education

Education				
	Other	High School	Master's degree	Ph.D
Amount	2	3	3	2
Percentage	20%	30%	30%	20%

Table 10: Participants by native language

Native Language			
	English	Hebrew	Arabic
Amount	5	3	2
Percentage	50%	30%	20%

Table 11: Participants by gender

Gender		
	Female	Male
Amount	4	6
Percentage	40%	60%

7.1.5.2 Technology used

Table 12: Participants technology used

	Low	Middle	High
Amount	9	0	1
Percentage	90%	0%	10%

	High	Middle	Low
Participant Number	2		1
			4
			5
			6
			7
			8
			9
			10
			11

7.1.5.3 TAP - Technology adoption propensity

Table 13: Participants technology adoption propensity

		High	Middle	Low
GROUP 1 - Belief that technology provides increased control and flexibility in life.	Participant Number	1	4	
		2	5	
		6	7	
		8		
		9		
		10		
		11		
GROUP 2 - Confidence in one's ability to quickly and easily learn to use new technologies, as well as a sense of being technologically	Participant Number	2	1	4
			7	5
				6
				8
				9
				10
				11
GROUP 3 - Being overly dependent on, and a	Participant Number	1	2	
		5	4	

TAP	
Mean	3.08
SD	1.4

feeling of being enslaved by, technology.		6 7 10	8 9 11	
GROUP 4 - Belief that technology increases one's chances of being taken advantage of by criminals or firms.	Participant Number	1 2 9 10	8	4 5 6 7 11
Total	Participant Number	1 2	6 7 8 9 10 11	4 5

7.1.5.4 NARS – Negative attitude toward robots scale

		High	Middle	Low
S1 - Negative Attitudes toward Situations	Participant Number	6	1	2
		8	9	4
			11	5
				7
				10
S2 - Negative Attitudes toward Social Influence of Robots	Participant Number	7	1	5
		8	2	
		11	4	
			6	
			9	
			10	
S3 - Negative Attitudes toward Emotions in Interaction with Robots	Participant Number	6	1	2
		8	4	5
		10	7	9
			11	
Total	Participant Number	6	1	2
		8	4	5
			7	
			9	
			10	
			11	

NARS	
Avg.	13.57
Std.	5.56

Table 14: Participants negative attitude toward robots scale

7.1.5.5 How physically active are you?

	Under- active	Under-active regular – light activities	Under-active regular	Active Moderate	Active Moderate Vigorous	Strength	Flexibility
Subject Number	10	5	4	2	1	1	1
		6	7		11		2
		8					4
		9					10
							11
Precentage	10%	40%	20%	10%	20%	10%	50%

Table 15: Participants physically activity level

7.1.6 Appendix G – Post questionnaires analysis

7.1.6.1 Evaluations of the robot as an exercise coach

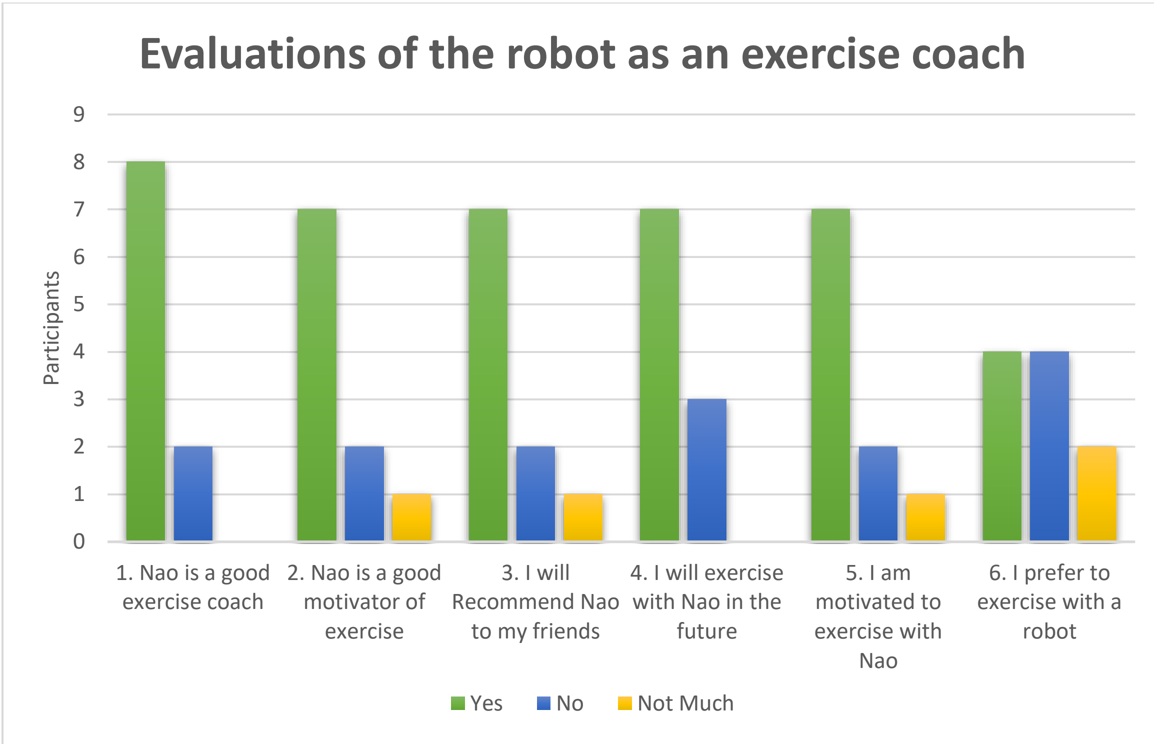
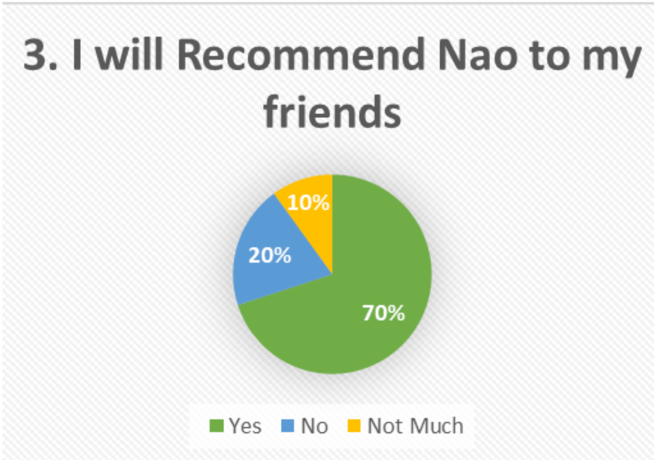
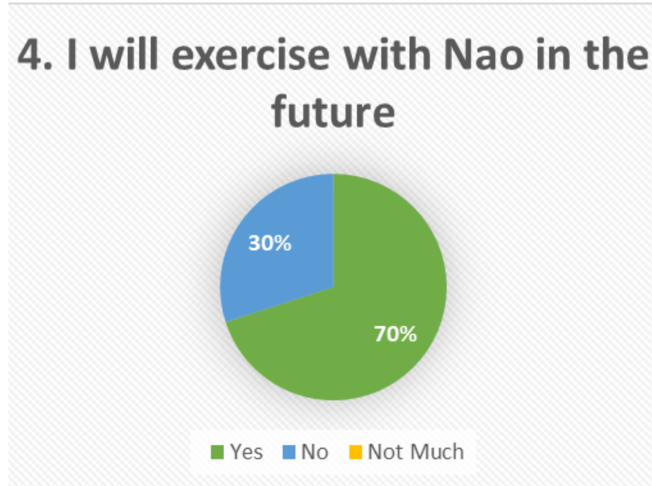
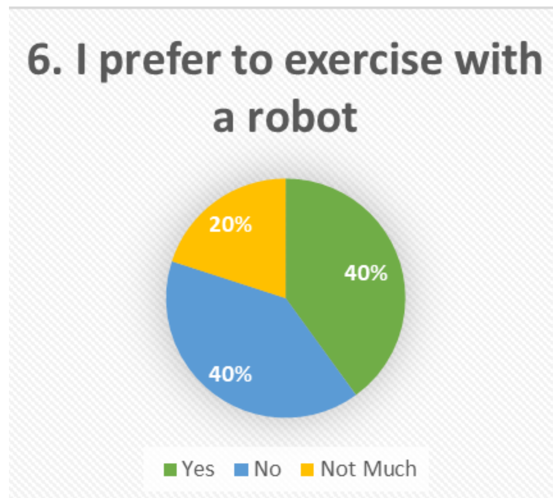


Figure 19: Participants evaluation of the robot as an exercise coach


3. I will Recommend Nao to my friends
10%
20%
70%
Yes
No
Not Much


4. I will exercise with Nao in the future
30%
70%
Yes
No
Not Much


5. I am motivated to exercise with Nao
10%
20%
70%
Yes
No
Not Much


6. I prefer to exercise with a robot
20%
40%
40%
Yes
No
Not Much

7.1.6.2 The social attraction

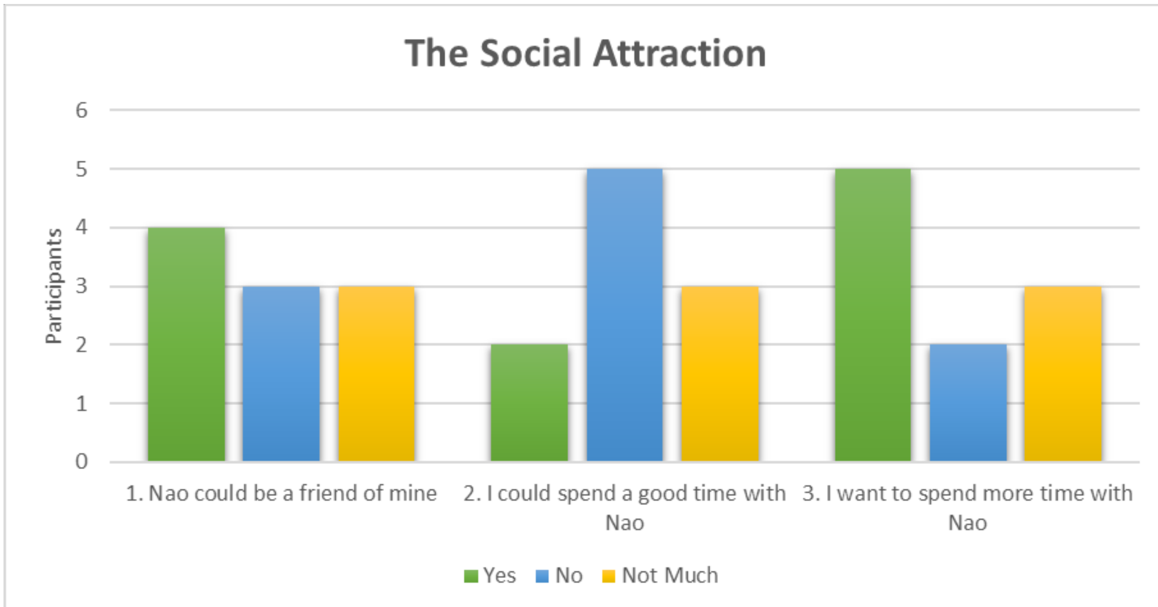
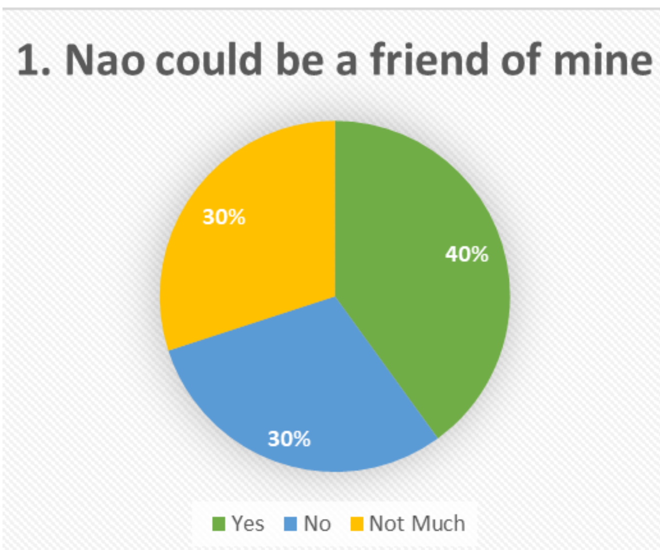
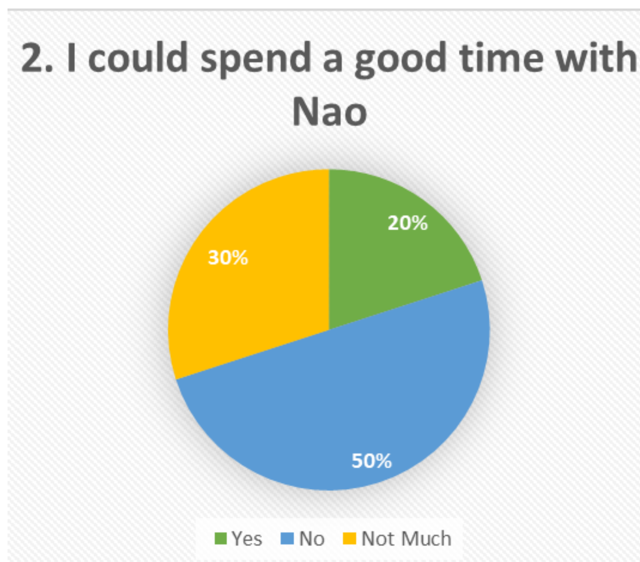
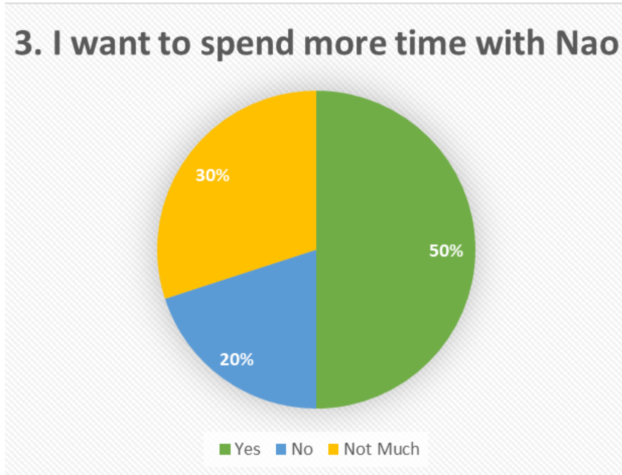


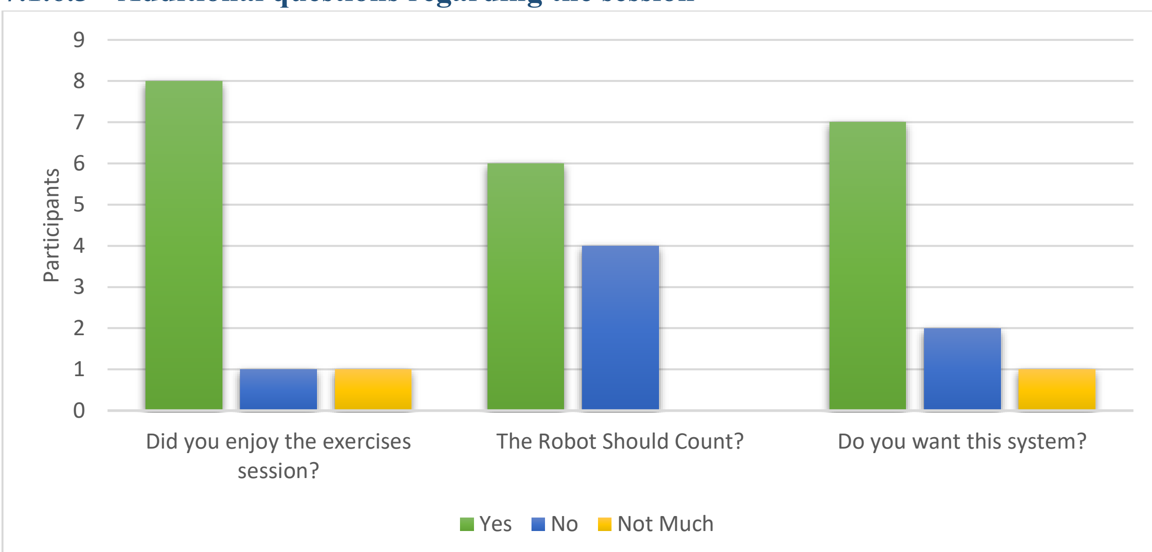
Figure 20: Participants evaluation of the social attraction

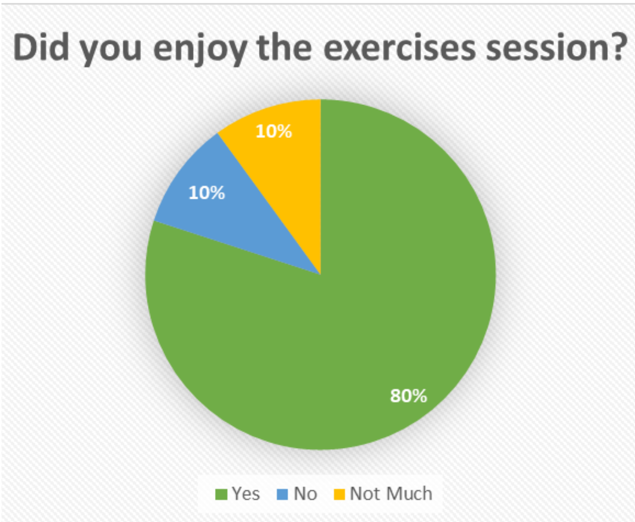


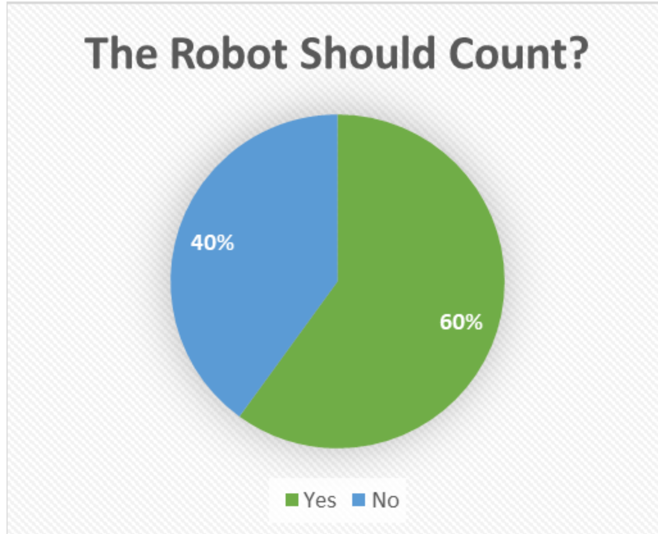


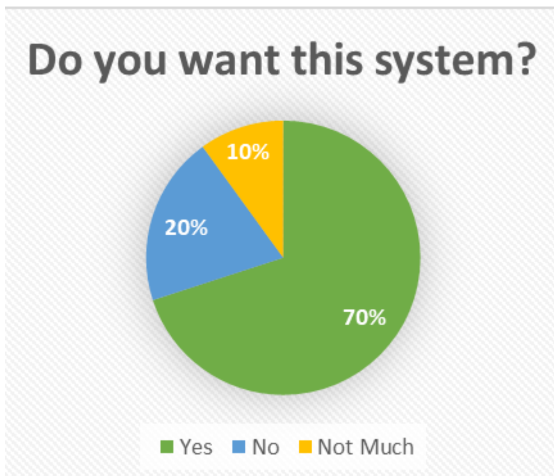


7.1.6.3 Additional questions regarding the session









7.1.7 Appendix H – Post interview – open coding

קטגוריה	משפטים שנאמרו
ספירת הרובוט	1. "מעדיף שיספור, זה עוזר לי עם הספירה ושולט בי" 2. "מעדיף שיספור, עוזר למעקב אחרי הרובוט עם הקצב והצורה. זה לא מפריע לי שהוא סופר כי אני סופר בכל מקרה וזה עוזר לי לוודא שאנחנו סופרים באותה הדרך" 4. "ספירה" 5. "מעדיף שיספור" 6. "אעדיף שלא יספור תוך כדי" 7. "אהבתי שמדבר, אשמח שיספור" 8. "מעדיפה שלא יספור, שלא יבלבל לי את הראש" 9. "מעדיף שיספור" 10. "ללא ספירה" 11. "מעדיף בלי ספירה"

החוויה והאינטראקציה עם המערכת	1. "היתה טובה, לא היתה לי בעיה , הייתי מסוגל לבצע כל מה שצריך" 2. "זה לא מרתק אבל זה היה טוב כמאמן אישי כי זה שומר בצורה יפה בעזרת הדיבור" 4. "נחמדה" 5. "סבירה" 6. "מאוד נהנתי. זה מעולה, אני מרגישה ששרירים שהם רפויים מדי משתפרים. זה ממש נחמד, הייתי מביאה לפה את כל הזקנים והם היו עובדים" 7. "נחמד. מאוד נהנתי מהתרגילים, הם היו טובים בכל מקרה. אהבתי שהוא דיבר אלי." 8. "מעניינת" 9. "טובה" 10. "מעניין" 11. "הייתי סקרן לגלות מה הולך לקרות"
מה היה טוב באינטרקאקציה עם המערכת?	1. "נהנתי מהספירה" 2. "אהבתי את האימון שבו ספר" 4. "הרובוט יפה, צבעוני, ורודה ונקבה!" 5. "ניכר שהמערכת במצב ראשוני" 6. "מאוד שקוף וברור, גם אם לא מבינים מה הוא אומר. התנועות מאוד נכונות וברורות. גורם לך לעשות דברים שלא עושים ביום יום, מאוד יפה" 7. "עשינו יחד ספורט" 8. "יכולה לעשות בבית, מול הטלוויזיה" 9. "הפלא הגדול, אני יכול לדבר איתו" 10. "שיש מישהו שמדגים" 11. "הניפוף להתראות"
מה היית רוצה לשפר במערכת?	2. "אשמח שתהיה לי אפשרות לשלוט במהירות, סוגי תרגילים נוספים. תגובות נוספות, "Good job", "Nice raising" ועוד." 4. "מהירות, היה לי איטי" 5. "מוזיקה, שידבר מהר יותרת שיהיה אינטרקאקטיבי יותר ויגיד למשתמש "אתה ובד לאט/מהר מדי" " 6. "שיתעדכן בהתאם לבעיות גיל. אם כואב הגב, יתאים תרגילים בהתאם למצב המתאמן" 7. "מספיק עבורי" 8. "עוד תרגילים, לא להוסיף סוגי פידבקים נוספים" 9. "הוראות יותר בהירות, דיבור יותר איטי" 10. "הרובוט איטי מדי" 11. "הקצב צריך להיות מהיר"
מה דעתך על משוב המערכת?	1. "טוב. הייתי מעדיף שלא ישאל אותי אם אני רוצה לעשות את התרגיל שוב במידה ולא הצלחתי." 2. "Corrective feedback טוב. הרשתי שהפידבק רובוטי genion." 4. "נחמד, אשמח לשלב פידבק ויזואלי" 5. "כל הכבוד" 6. "החיזוק מאוד מאוד יפה. במידה ולא הצלחתי לבצע את התרגיל, אשמחר שיגיד לי לשפר את התרגיל." 7. "סביר" 8. "טוב"

	9. "מוצלח, צריך עוד צורות פידבקים חיוביים / שליליים" 10. "שיגדיר מה הבעיה, לדוגמא "אתה עושה מהיר מדי" 11. "נוח"
האם אתה מעוניין במערכת כזו?	1. "אם היתה לי אפשרות הייתי שמח לקנות" 2. "אני מעדיף ללכת לחדר כושר. אני אוהב לצאת החוצה ולהתאמן, אף פעם לא מסוגל לבצע דברים בבית, מעדיף במקום חיצוני. גם כשאהיה במצב תפקודי פחות טוב, לא ארצה כי אני מעדיף להתאמן בעצמי. יכול להתאים לאישתי, אולי יעשה לה תרגילים לצוואר. אם הרובוט היה מלמד אותי תרגילים חדשים -אז כן." 4. "כן" 5. "כן אחרי שיפורי מהירות ומשוב רלוונטיים" 6. "כן" 7. "לא" 8. "כן" 9. "כן" 10. "כן, אחרי שיפורי מהירות ומשוב רלוונטיים" 11. "לא ממש, אני אוהב לעשות הליכות בחוץ"
האם שימוש במערכת כזו לאורך זמן יכול לגרום לך לבצע יותר פעילות גופנית?	1. "לא בטוח שלאורך זמן יגרום לי לעשות יותר פעילות גופנית" 2. "לא" 4. "כן" 5. "לא, בבתי אבות יכול להיות יותר טוב, מתאים לאנשים יותר מבוגרים" 6. "כן, אני מתעצלת להתלבש ולצאת" 7. "כן" 8. "בהחלט" 9. "כן" 10. "כן" 11. "בשבילי לא כי אני עושה הרבה הליכות, אבל כן לאנשים הצריכים מוטיבציה כדי להתאמן"
ההבדל בין אימון ע"י רובוט ואימון ע"י בן אדם מבחינתך?	1. "חיסרון לרובוט - אי אפשר לשאול רובוט יותר שאלות כמו שאפשר לקבל מבני אדם. יתרון עתידי, עוד לא יודע להגיד כי זה הפעם הראשונה שעובד עם רובוט" 2. "אנשים מסתגלים מהר יותר, נותנים פידבק מתקן. רובוט יהיה קשה יותר. אבל יכול להיות במידה ויטפל בתרגילים קשים" 4. "בן אדם יותר מדויק, רובוט – מתי שרוצים. לא צריך להתלבש יפה" 5. "רובוט – מתי ואיפה שרוצים" 6. "כיף שיכול להיות בבית, לא צריך ללכת לשום מקום. בן אדם יכולה לדבר חופשי, תרגיל מסוים קשה , תרגיל קל. תתקדם הלאה.." 7. "עם רובוט יותר משעשע" 8. " רובוט - אצלך בבית, מול הטלוויזיה. כל שעה שיכולה." 9. "בן אדם = מתייחס אליו, רצונות, מחשבות. רובוט – מה שתחשוב עליו לא יגיע אליו. מעדיף להתאמן עם רובוט." 10. "רובוט מתי ואיפה שרוצים" 11. "עם רובוט יש פחות מתח, פחות לחץ נפשי"
איזה סכום היית מוכן לשלם עבור המערכת	1. 1000$ או יותר 2. 100$ אולי זה עדיף ממערכת עם רובוט כי זה יותר יעיל ופחות יקר ממערכת עם רובוט

	4. 400 ש"ח 5. 50 ש"ח 6. 2000 ש"ח 7. 0 8. 1000 ש"ח 9. 5000 ש"ח 10. "לא יודע" 11. "250$, כל סכום הנדרש בשביל לרכוש"
מה היית רוצה לקבל מהמערכת בנוסף?	1. "כלום" 2. "מוזיקה, להקריא סיפורים, אולי לעשות רובוט עם מסך עליו. שמקריא סיפור תוך כדי, מקרין סרט, באמצעות טבלט שיהיה על הרובוט." 4. "דיוק" 5. "יכול להיות טוב בספניניג, הליכון, להוסיף שעון דופק" 6. "להוסיף מוזיקה ברקע" 7. "יותר תרגילים, לקפוץ יחד" 8. "תרגילים נוספים, מוזיקה ברקע" 9. "מוזיקה ברקע" 10. "מוזיקה, פידבק יותר רלוונטי" 11. "מגוון גדול יותר של תרגילים"
מה חשבת על הרובוט?	1. נלהב מאוד מהרובוט. לא מפחיד בעיניו. רצה לגעת ולחוש ברובוט ישר. 2. "חמוד, יש תרגילים שלא יוכל לעשות כמו תרגילי צוואר" 4. "חמוד" 5. "כלום" 6. "חמוד מאוד" 7. "שעשוע" 8. "צעצוע יפה. מעדיפה על המסך, לא רוצה עוד צעצועים בבית ובנכדים יהרסו אותו." 9. "חמוד, מעדיף על מסך" 10. "חמוד" 11. "נחמד, מעדיף במסך כי מבוגרים רגילים לשימוש במסך טלוויזיה ומחשב"
איזה סכום היית מוכן לשלם עבור המערכת עם הרובוט?	1. "לא יודע" 2. "מתחת ל1000$, תלוי כמה יכולות יהיו לו" 4. "4000 ש"ח" 5. "500 ש"ח" 6. "4000-5000 ש"ח" 7. "0 כי אני מעדיף הליכה בחוץ" 8. "מעדיפה על המסך" 9. "לא מוכן לשלם" 10. "לא מוכנה לשלם, איפה אני אשים אותו" 11. "לא יודע"

7.1.8 Appendix I – Post interview – Axial coding

	קטגוריה	משפטים שנאמרו
מערכת	החוויה והאינטראקציה עם המערכת	1. "היתה טובה, לא היתה לי בעיה , הייתי מסוגל לבצע כל מה שצריך" 2. "זה לא מרתק אבל זה היה טוב כמאמן אישי כי זה שומר בצורה יפה בעזרת הדיבור" 4. "נחמדה" 5. "סבירה" 6. "מאוד נהנתי. זה מעולה, אני מרגישה ששרירים שהם רפויים מדי משתפרים. זה ממש נחמד, הייתי מביאה לפה את כל הזקנים והם היו עובדים" 7. "נחמד. מאוד נהנתי מהתרגילים, הם היו טובים בכל מקרה. אהבתי שהוא דיבר אלי." 8. "מעניינת" 9. "טובה" 10. "מעניין" 11. "הייתי סקרן לגלות מה הולך לקרות"
	מה היית רוצה לשפר במערכת?	2. "אשמח שתהיה לי אפשרות לשלוט במהירות, סוגי תרגילים נוספים. תגובות נוספות, "Good job", "Nice raising" ועוד." 4. "מהירות, היה לי איטי" 5. "מוזיקה, שידבר מהר יותרת שיהיה אינטרקאקטיבי יותר ויגיד למשתמש "אתה ובד לאט/מהר מדי" " 6. "שיתעדכן בהתאם לבעיות גיל. אם כואב הגב, יתאים תרגילים בהתאם למצב המתאמן" 7. "מספיק עבורי" 8. "עוד תרגילים, לא להוסיף סוגי פידבקים נוספים" 9. "הוראות יותר בהירות, דיבור יותר איטי" 10. "הרובוט איטי מדי" 11. "הקצב צריך להיות מהיר"
	מה היית רוצה לקבל מהמערכת בנוסף?	1. "כלום" 2. "מוזיקה, להקריא סיפורים, אולי לעשות רובוט עם מסך עליו. שמקריא סיפור תוך כדי, מקרין סרט, באמצעות טבלט שיהיה על הרובוט." 4. "דיוק" 5. "יכול להיות טוב בספניניג, הליכון, להוסיף שעון דופק" 6. "להוסיף מוזיקה ברקע" 7. "יותר תרגילים, לקפוץ יחד" 8. "תרגילים נוספים, מוזיקה ברקע" 9. "מוזיקה ברקע" 10. "מוזיקה, פידבק יותר רלוונטי" 11. "מגוון גדול יותר של תרגילים"
פידבק	מה דעתך על משוב המערכת?	1. "טוב. הייתי מעדיף שלא ישאל אותי אם אני רוצה לעשות את התרגיל שוב במידה ולא הצלחתי." 2. "Corrective feedback טוב. הרשתי שהפידבק רובוטי genion." 4. "נחמד, אשמח לשלב פידבק ויזואלי"

		5. "כל הכבוד" 6. "החיזוק מאוד מאוד יפה. במידה ולא הצלחתי לבצע את התרגיל, אשמחר שיגיד לי לשפר את התרגיל." 7. "סביר" 8. "טוב" 9. "מוצלח, צריך עוד צורות פידבקים חיוביים / שליליים" 10. "שיגדיר מה הבעיה, לדוגמא "אתה עושה מהיר מדי" 11. "נוח"
	ספירת הרובוט	1. "מעדיף שיספור, זה עוזר לי עם הספירה ושולט בי" 2. "מעדיף שיספור, עוזר למעקב אחרי הרובוט עם הקצב והצורה. זה לא מפריע לי שהוא סופר כי אני סופר בכל מקרה וזה עוזר לי לוודא שאנחנו סופרים באותה הדרך" 4. "ספירה" 5. "מעדיף שיספור" 6. "אעדיף שלא יספור תוך כדי" 7. "אהבתי שמדבר, אשמח שיספור" 8. "מעדיפה שלא יספור, שלא יבלבל לי את הראש" 9. "מעדיף שיספור" 10. "ללא ספירה" 11. "מעדיף בלי ספירה"
	מה היה טוב באינטרקאקציה עם המערכת?	1. "נהנתי מהספירה" 2. "אהבתי את האימון שבו ספר" 4. "הרובוט יפה, צבעוני, ורודה ונקבה!" 5. "ניכר שהמערכת במצב ראשוני" 6. "מאוד שקוף וברור, גם אם לא מבינים מה הוא אומר. התנועות מאוד נכונות וברורות. גורם לך לעשות דברים שלא עושים ביום יום, מאוד יפה" 7. "עשינו יחד ספורט" 8. "יכולה לעשות בבית, מול הטלוויזיה" 9. "הפלא הגדול, אני יכול לדבר איתו" 10. "שיש מישהו שמדגים" 11. "הניפוף להתראות"
אימוץ המערכת	האם אתה מעוניין במערכת כזו?	1. "אם היתה לי אפשרות הייתי שמח לקנות" 2. "אני מעדיף ללכת לחדר כושר. אני אוהב לצאת החוצה ולהתאמן, אף פעם לא מסוגל לבצע דברים בבית, מעדיף במקום חיצוני. גם כשאהיה במצב תפקודי פחות טוב, לא ארצה כי אני מעדיף להתאמן בעצמי. יכול להתאים לאישתי, אולי יעשה לה תרגילים לצוואר. אם הרובוט היה מלמד אותי תרגילים חדשים -אז כן." 4. "כן" 5. "כן אחרי שיפורי מהירות ומשוב רלוונטיים" 6. "כן" 7. "לא" 8. "כן" 9. "כן" 10. "כן, אחרי שיפורי מהירות ומשוב רלוונטיים" 11. "לא ממש, אני אוהב לעשות הליכות בחוץ"

	האם שימוש במערכת כזו לאורך זמן יכול לגרום לך לבצע יותר פעילות גופנית?	1. "לא בטוח שלאורך זמן יגרום לי לעשות יותר פעילות גופנית" 2. "לא" 4. "כן" 5. "לא, בבתי אבות יכול להיות יותר טוב, מתאים לאנשים יותר מבוגרים" 6. "כן, אני מתעצלת להתלבש ולצאת" 7. "כן" 8. "בהחלט" 9. "כן" 10. "כן" 11. "בשבילי לא כי אני עושה הרבה הליכות, אבל כן לאנשים הצריכים מוטיבציה כדי להתאמן"
	איזה סכום היית מוכן לשלם עבור המערכת	1. 1000$ או יותר 2. 100$ אולי זה עדיף ממערכת עם רובוט כי זה יותר יעיל ופחות יקר ממערכת עם רובוט 4. 400 ש"ח 5. 50 ש"ח 6. 2000 ש"ח 7. 0 8. 1000 ש"ח 9. 5000 ש"ח 10. "לא יודע" 11. "250$, כל סכום הנדרש בשביל לרכוש"
מערכת עם הרובוט	ההבדל בין אימון ע"י רובוט ואימון ע"י בן אדם מבחינתך?	1. "חיסרון לרובוט - אי אפשר לשאול רובוט יותר שאלות כמו שאפשר לקבל מבני אדם. יתרון עתידי, עוד לא יודע להגיד כי זה הפעם הראשונה שעובד עם רובוט" 2. "אנשים מסתגלים מהר יותר, נותנים פידבק מתקן. רובוט יהיה קשה יותר. אבל יכול להיות במידה ויטפל בתרגילים קשים" 4. "בן אדם יותר מדויק, רובוט – מתי שרוצים. לא צריך להתלבש יפה" 5. "רובוט – מתי ואיפה שרוצים" 6. "כיף שיכול להיות בבית, לא צריך ללכת לשום מקום. בן אדם יכולה לדבר חופשי, תרגיל מסוים קשה , תרגיל קל. תתקדם הלאה.." 7. "עם רובוט יותר משעשע" 8. " רובוט - אצלך בבית, מול הטלוויזיה. כל שעה שיכולה." 9. "בן אדם = מתייחס אליו, רצונות, מחשבות. רובוט – מה שתחשוב עליו לא יגיע אליו. מעדיף להתאמן עם רובוט." 10. "רובוט מתי ואיפה שרוצים" 11. "עם רובוט יש פחות מתח, פחות לחץ נפשי"
	מה חשבת על הרובוט?	1. נלהב מאוד מהרובוט. לא מפחיד בעיניו. רצה לגעת ולחוש ברובוט ישר. 2. "חמוד, יש תרגילים שלא יוכל לעשות כמו תרגילי צוואר" 4. "חמוד" 5. "כלום" 6. "חמוד מאוד"

		7. "שעשוע" 8. "צעצוע יפה. מעדיפה על המסך, לא רוצה עוד צעצועים בבית ובנכדים יהרסו אותו." 9. "חמוד, מעדיף על מסך" 10. "חמוד" 11. "נחמד, מעדיף במסך כי מבוגרים רגילים לשימוש במסך טלוויזיה ומחשב"
	איזה סכום היית מוכן לשלם עבור המערכת עם הרובוט?	1. "לא יודע" 2. "מתחת ל1000$, תלוי כמה יכולות יהיו לו" 4. "4000 ש"ח" 5. "500 ש"ח" 6. "4000-5000 ש"ח" 7. "0 כי אני מעדיף הליכה בחוץ" 8. "מעדיפה על המסך" 9. "לא מוכן לשלם" 10. "לא מוכנה לשלם, איפה אני אשים אותו" 11. "לא יודע"

7.2 Main study

7.2.1 Appendix J – BGU ethical committee

Research Protocol:

The research protocol should contain a full description of the project stages that pertain to the experimental method and all interaction with the human subjects. If the project contains a series of experiments, describe the variations; also include description of type and number of subjects and subject recruitment method. If this type of protocol is one commonly used and/or if a similar protocol and methods have been used and published in the literature, please add references indicating so. Please do not submit the complete project proposal that was submitted to the funding agency, the protocol should be maximum 2 pages long.

The experiment already received permission(Attached approved request). This experiment different because of its include additional robot; "Poppy".

Purpose:

The aim of the experiment is to examine the effectiveness of the system in motivating seniors to do physical activity.

Subjects:

Participants will be seniors(older than 60) in good health. Participation in the research will be on a voluntary basis and will require signing an informed consent for approval. The recruitment will be done by publishing advertisement (via university, social networks etc.) and invitation to contact the experimenters.

Procedure:

At the recruitment stage, participants will be asked regarding their health condition. Participants whose health will not be good enough will not be able to participate in the experiment.

In the beginning, the subjects will sign a consent form and fill a preliminary questionnaire which will include details about their current health condition. Then, they will be asked to fill few preliminary questionnaires (including demographic details, physical fitness level (an online questionnaire), TAP (Ratchford & Barnhart, 2012) and NARS (Taylor Katz & Halpern, 2013). In addition, during the experiment, the participant will be able to stop the experiment by raising his hand or saying they want to quit. In this case, the eperiementer will immediately stop the eperiement and approach the participant for help.

Before experimenting the use of the system on the subjects, the researcher will explain them about the system, how it works and about the procedure of the experiment. First, the robot will introduce itself to the participants and will provide them a brief explanation of the training.

During the experiment, the robot will demonstrate the subjects some physical activity exercise and the subjects will need to imitate the robot and repeat the exercises. The excercises will be of low-intensity level like standing in the place and raising his hands to shoulders level, uses a chair as support and raises his legs to the side. The duration of each exercise will be up to 1 minutes. The total time of the whole session will be 15 minutes.

The robot will provide the subjects verbal feedback according to their execution.

During the experiment, there will be no physical contact between the subject and the robot. Therefore, no risk will exist during the experiment.

At the end of the training, subjective assessments will be conducted using questionnaires and interviews. The subjective assessment tools will be used to evaluate and identify dimensions of user acceptance (or unacceptance of the technology), satisfaction and trust.

Measurements:

At the end of each scenario, subjective assessments will be conducted using questionnaires.

References:

- Ratchford, M., & Barnhart, M. (2012). Development and validation of the technology adoption propensity (TAP) index. Journal of Business Research, 65(8), 1209–1215.
- Taylor, P., Katz, J. E., & Halpern, D. (2013). Behaviour & Information Technology Attitudes towards robots suitability for various jobs as affected robot appearance, (July 2014), 37–41.

I. General

Name of Research Project: Developing a Physical Robotics System for Older Adults

To which agency is the proposal being submitted (or has been submitted): CDI

Principal Investigator/s (or academic supervisor/s):

Name: **Yael Edan**	**Name**: **Vardit Fleischmann**
Department: IEM	**Department:** IEM
Academic position: Prof	**Academic position:**
University Telephone: 08-6472232	**University Telephone**:
Mobile Phone: 052-3683931	**Mobile Phone:**
University Email: yael@bgu.ac.il	**University Email:** varditf@gmail.com
Other Email:	**Other Email:**

Name(s) of those conducting the research (if different from above):

Name: Omri Sarig	**Name**: -
Department: IEM	**Department:** -
Academic position: Student	**Academic position:** -
University Telephone: -	**University Telephone**: -
Mobile Phone: 054-7418881	**Mobile Phone:** -
Email: sarigomr@post.bgu.ac.il	**Email:** -

II. Consent to Participate

1. Are the subjects able to legally consent to participate in the research? ☒ Yes / ☐ No

   If you answered 'No' to question 1, complete section IIb

2. Will the subjects be asked to sign a consent form? ☒ Yes / ☐ No

   If you answered 'No' to question 2, explain here:

IIb: Subjects who cannot legally consent (minors, mentally incapacitated, etc.):

3. Will the subject's legal guardian be asked to sign a consent form? ☐ Yes / ☐ No

   If you answered 'No', to question 3, please explain here:

4. Will the subject be asked to give oral consent? ☐ Yes / ☐ No

5. Are the instructions appropriate to the subjects' level of understanding? ☐ Yes / ☐ No

Comments:

6. If informed consent forms will be signed, how will the informed consent forms be stored to ensure confidentiality? All signed forms will be saved in a locked cabinet.

III. Discomfort:

7. Will the participants be subjected to physical discomfort? ☐ Yes / ☒ No

8. Will the participants be subjected to psychological discomfort?: ☐ Yes / ☒ No

   If you answered 'Yes' to question 7 or 8, add here a detailed explanation of the circumstances:

IV. Deception

9. Does the research involve deceiving the subjects? ☐ Yes / ☒ No

10. Is the decision on the part of the subject to participate in the study based on deception? (For example, if they are informed of their participation only after the event.) ☐ Yes / ☒ No

    If you answered 'Yes' to question 9 or 10, add here a detailed explanation why deception is necessary:

V. Feedback to the Subject

Note: Although feedback to the subject is recommended for *all* studies, it is required for studies that involve discomfort or deception. Feedback entails providing the subject, upon completion of the experiment, explanation of the experiment and its aims.

11. Will the subjects be provided with post-experiment oral feedback? ☒Yes / ☐ No

12. Will the subjects be provided with post-experiment written feedback? ☒Yes / ☐ No

If you answered 'No' to both questions 11 and 12, explain here:

VI. Compensation for Participation

13. Will the subjects receive compensation for participation? ☐Yes / ☒ No

Detail here the type and amount of compensation:

If you answered 'No' to question 13, explain the basis for participation: It will be informed to the subjects that the experiment is performed volunteerly.

VII. Privacy:

14. Will audio and/or visual recordings be made of the subjects? ☒Yes / ☐ No

   a. If yes, are they informed of this fact in the informed consent form? ☒Yes / ☐ No

15. Will the data collected (apart from the informed consent form) contain identifying details about the subjects? ☒Yes / ☐ No

   a. If the data contains identifying details, please answer here: (1) What steps will you take to ensure the confidentiality of the information? (2) How will the data be stored? (3) What will be done with identifying information or recordings of the subjects at the end of the research? The only data which will contain identifying details (except from the consent form) will be the audio and video files (of the participants while using the system). All data files will be encoded by password and saved in the researchers' PCs.

VIII. Withdrawal from the Study:

16. Will subjects be informed that they may withdraw from the study at any time? ☒ Yes / ☐ No
17. Will the subjects' compensation for participation be affected if they withdraw from the study before its completion? ☐ Yes / ☒ No
    a. If yes, are they informed of this fact in the informed consent form? ☐ Yes / ☐ No

IX. Research Equipment

18. Does the research entail the use of equipment other than standard equipment, such as computers, video recording equipment? ☒ Yes / ☐ No
19. If yes, does the equipment being used meet safety standard for use with human subjects? ☒ Yes / ☐ No

Please specify which standards (include documentation where appropriate):

The robotic system will include Nao's robot 6 (https://www.ald.softbankrobotics.com/en/robots/nao), (which complies with the IEC/EN 60950 safety standard), Poppy's robot which is designed as a research product, thus it does not have any specific safety standard document. The parts taken individually (electronics, servos...) have CE compliance and a Kinect camera(which complies with the ISO Standard 16331-1). The Kinect will enable to analyze the movements of the subject and Nao will instruct and demonstrate the exercises as their personal coach. There is no physical contact between the robot and the subject. The robot is positioned 1.5 meter away from the participant. In addition, we will use a simulator that will present on a screen and will include a demonstration of Nao's and Poppy's robot.

Signatories:

Name: Yael Edan **Position:** Professor

Signature: ____________ **Date:**

Name: Omri Sarig **Position:** Student

Signature: ____________ **Date:** 14/03/19

This section is to be filled out by a member of the Human Subjects Research Committee only

Decision of the Committee:

Note: The decision of this committee pertains only to ethical considerations involved in the conduct of the research.

Request Number:

Request Sub-Number:

Title of Research Project:

Principal Investigator/s:

Approval for research: ☐ Granted / ☐ Denied

Comments to the researcher in the event that application has been denied:

<u>טופס הסבר לנבדק</u>

<u>טופס הסכמת הנבדק להשתתפות בניסוי</u>

<u>נושא המחקר: פיתוח מערכת רובוטית לאימון מבוגרים</u>

*גוף השאלון מנוסח בלשון זכר מטעמי נוחות והינו מכוון לשני המינים

נבדק יקר,

בבקשה קרא את דף ההסבר באשר לניסוי. במידה ויש שאלות, נשמח לענות.
בבקשה וודא כי הנך מבין היטב את שלבי המחקר.

במהלך הניסוי תתבקש לבצע אימון גופני באמצעות רובוט שיהיה המאמן האישי שלך.

המחקר הנוכחי נערך באוניברסיטת בן-גוריון ועוסק באימון גופני באמצעות רובוט .

במסגרת המחקר תבצע אימון של 15 דקות בהדרכתו של הרובוט. הרובוט ידגים וינחה אותך איזה תרגיל לבצע כל פעם.

חשוב לציין כי הניסוי הוא אנונימי וכי לא מתבצעת שמירה של הפרטים המזהים של הנבדקים. כל נבדק מקבל מספר נבדק אשר מופרד מפרטי הנבדק וכל השאלונים שימולאו יימסרו לחוקרת הראשית הממונה על המחקר וישמרו באחריותה.

אם מכל סיבה שהיא הינך חש שלא בנוח, בבקשה עצור את הניסוי באמצעות הרמת יד או בקשה מילולית ועורכת הניסויים תיגש אליך באופן מיידי. בכל עת ובכל שלב תוכל, אם תרצה, להפסיק את השתתפותך במחקר. במידה ורצונך כי הניסוי ייפסק, תשוחרר מהניסוי.

אני החתום מטה *:

שם פרטי ומשפחה:	ת.ז.
חתימה:	טלפון:

א. מצהיר/ה בזה כי אני מסכים/ה להשתתף בניסוי, כמפורט במסמך המפרט את חלקי הניסוי.

ב. מצהיר/ה בזה כי אני במצב בריאותי תקין המאפשר לי לבצע פעילות גופנית. אנא סמן וי ליד הפעיליות שאתה מסוגל לעשות

- □ אני מסוגל לעלות 5 מדרגות ברצף בלי הפסקה
- □ אני מסוגל לבצע הליכה של 15 דקות ברציפות
- □ אני מסוגל להרים ידיים / רגליים
- □ אני מסוגל לשבת על כיסא

ג. מצהיר/ה שהוסברו לי בפירוט כל חלקי הניסויי והסכמתי ליטול בו חלק לאחר שנענו כל שאלותיי לגבי כל אחד מחלקי הניסוי.

ד. מצהיר/ה בזה כי הוסבר לי על-ידי החוקרת: ________________

- □ כי אני חופשי לבחור שלא להשתתף בניסוי וכי אני חופשי להפסיק בכל עת את השתתפותי בניסוי מכל סיבה שהיא.
- □ במידה ואני חש ברע או באי נוחות במהלך הניסוי חובה עלי לדווח לנסיין על מנת להפסיק את הניסוי.
- □ מובטח שזהותי האישית תשמר סודית על-ידי כל העוסקים והמעורבים במחקר ולא תפורסם בכל פרסום כולל בפרסומים מדעיים, אלא אם כן אאשר זאת בחתימתי.
- □ מובטחת לי נכונות לענות לשאלות שיועלו על-ידי.

ייתכן ובמהלך הניסוי החוקרים יצלמו תמונות וסרטונים לצורכי מחקר בלבד.

במידה ואתה מאשר\ת זאת חתום כאן : ________________

במידה ואת\ה מסכימים שתמונתכם תופיע בפרסומים שונים שיוצגו לציבור אנא ציינו:

☐ אני מסכים שתמונתי תופיע בפרסומים שונים

☐ איני מעוניין שתמונתי תופיע

* הצהרה זו הנה סודית ואינה ניתנת להעברה או שימוש לצורך שום דבר או גורם אחר פרט לצורכי מחקר זה.

תאריך ________________ חתימת מעביר הניסוי ______________

חתימת המשתתף/ת בניסוי ______________

אנו מודים לך על השתתפותך במחקר.

לפרטים נוספים ניתן לפנות ל:

פרופ' יעל אידן בטלפון 08-6472232 או בדוא"ל yael@bgu.ac.il

עמרי שריג בטלפון 054-7418881 או בדוא"ל sarigomr@post.bgu.ac.il

VIEW OPTIONS FOR REQUEST

1605-2

Request Details | Request Files | Request Status

Submission Details:

Request Sub-Number:	**1605-2**
Request Number:	**1605**
Request Type:	**Repeat Request**
Submitted By:	**Student Sarig Omri** **E-mail: sarigomr@post.bgu.ac.il** **Phone: 0547418881**
Submission Date:	**Monday, April 16, 2018**

Research and Agency Name:

Research Name:	**Developing a Physical Robotics System for Older Adults**
Submitted To The Agency:	**CDI**

Principal Investigator/s (or academic supervisor/s):

Name:	**Prof. Yael Edan**
Department:	**Industrial Engineering and Management**
Phone:	**052-3683931**
E-mail:	**yael@bgu.ac.il**
Name:	**Ph.D. Vardit Fleischmann**
Department:	**Industrial Engineering and Management**
Phone:	
E-mail:	**varditf@gmail.com**

Name/s of those conducting the research:

Name:	**Student Sarig Omri**
Department:	**industrial engineering and management**
Phone:	**0547418881**
E-mail:	**sarigomr@post.bgu.ac.il**
Name:	
Department:	
Phone:	
E-mail:	

7.2.2 Appendix K – Pre-questionnaires

TAP	
1	Technology gives me more control over my daily life.
2	New technologies make my life easier.
3	I can figure out new high-tech products and services without help from others.
4	I enjoy figuring out how to use new technologies.
5	Technology controls my life more than I control technology.

NARS	
1	I would feel relaxed talking with robots.
2	I would feel uneasy if I was given a job where I had to use robots.
3	The idea that robots can make judgments about things excites me.
4	I would feel very nervous standing in front of a robot.
5	I feel that if I depend on robots too much, something bad might happen.

7.2.3 Appendix L – Post trail questionnaires

Post Trail Questionnaires
I concentrated on the activity for the entire session
I was satisfied by the robot's performance during this activity.
I felt nervous during the activity
I would be willing to train with the robot again because it had value to me
I felt like I could really trust this robot
I put a lot of effort into this activity.
I understood the robot well during the interaction.
I felt comfortable during the interaction.
I Were eager to finish the exercises
I enjoyed the activity
I would like to exercise with the robot in the future

7.2.4 Appendix M – Final questionnaires

Question	Answer
Should the robot count the exercise repetitions?	Yes / No
Which robot did you understand best?	Poppy / Nao / Both / None
Which system would you choose to use?	Poppy / Nao / Both / None
I would like to exercise with the robot in the future.	Yes / No

7.2.5 Appendix N – Preliminary questionnaires analysis

Table 16: TAP analysis

	High	Middle	Low	AVG	SD
GROUP 1 - Belief that technology provides increased control and flexibility in life.	80.65%	6.45%	12.90%	4.0	1.20
GROUP 2 - Confidence in one's ability to quickly and easily learn to use new technologies, as well as a sense of being technologically competent.	32.26%	25.81%	41.94%	3	1.26
GROUP 3 - Being overly dependent on, and a feeling of being enslaved by, technology.	58.06%	35.48%	6.45%	3.5	0.75
TOTAL	58.06%	38.71%	3.23%	3.54	0.65

Table 17: NARS analysis

	High	Middle	Low	AVG	SD
S1 - Negative Attitudes toward Situations and Interactions with Robots	12.90%	51.61%	35.48%	2.84	0.62
S2 - Negative Attitudes toward Social Influence of Robots	22.58%	25.81%	51.61%	3.00	1.36
S3 - Negative Attitudes toward Emotions in Interaction with Robots	64.52%	9.68%	25.81%	3.45	1.29

7.2.6 Appendix O – Post-trails questionnaires analysis

Table 18: Subjective evaluation of the training

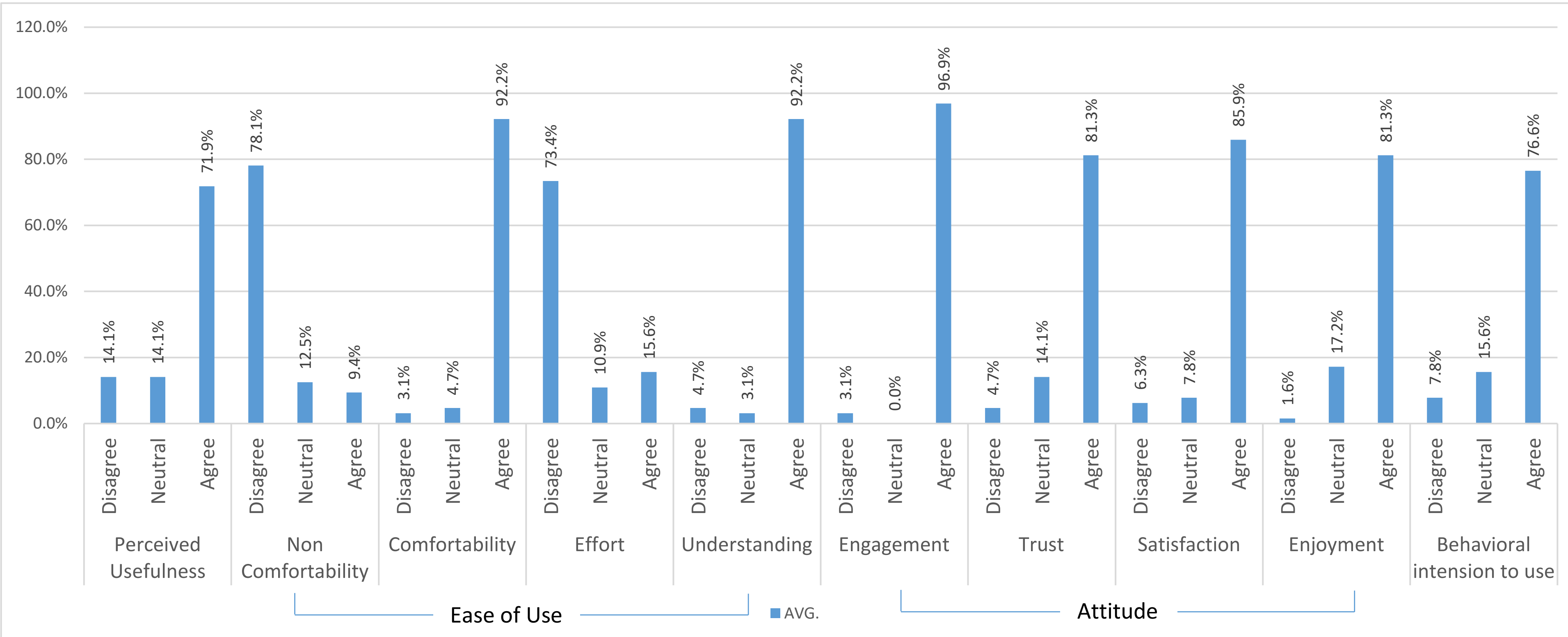


Table 19: Subjective evaluation of the training - type of robot

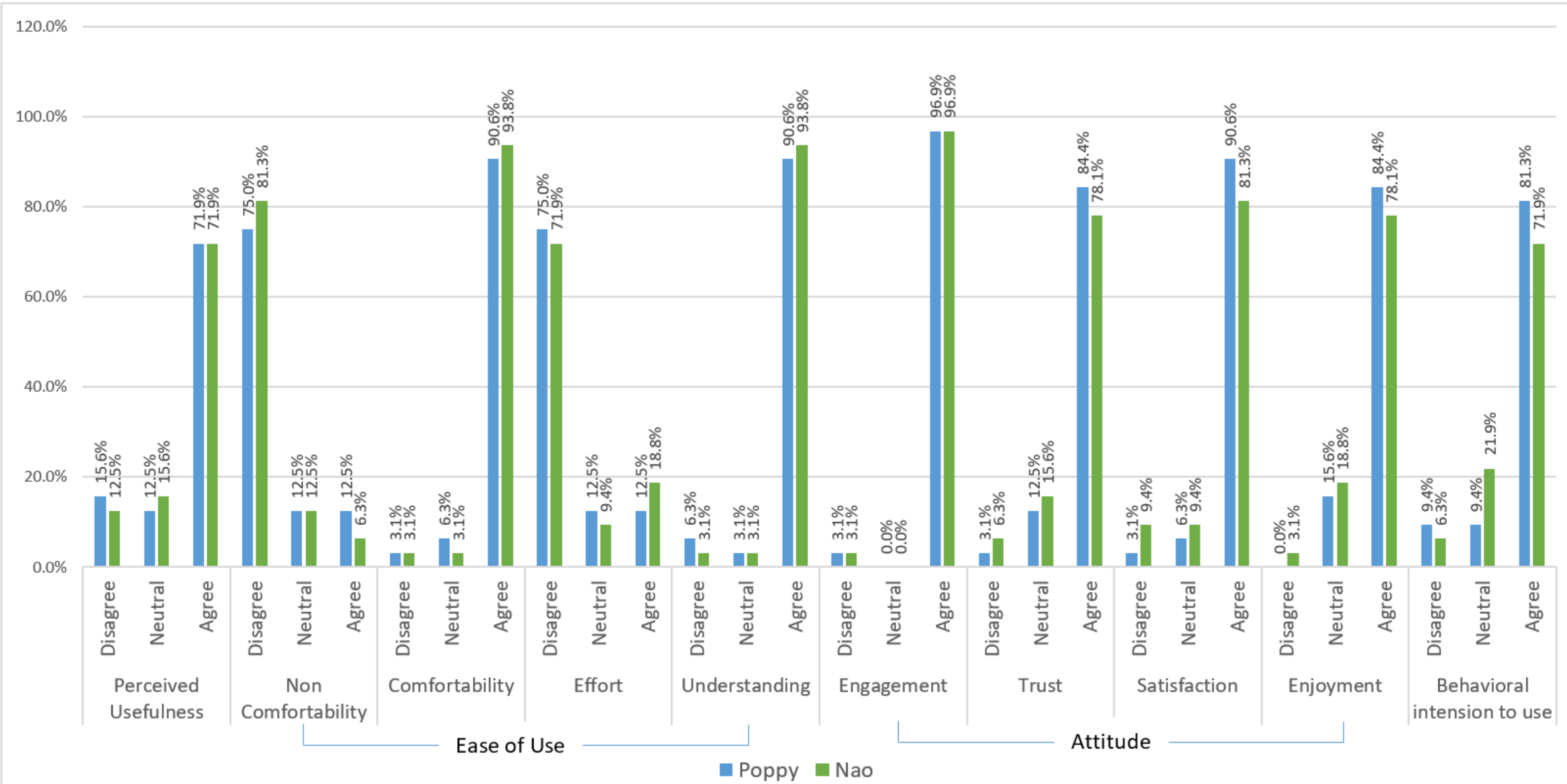


Table 20: Subjective evaluation of the training - mode of feedback

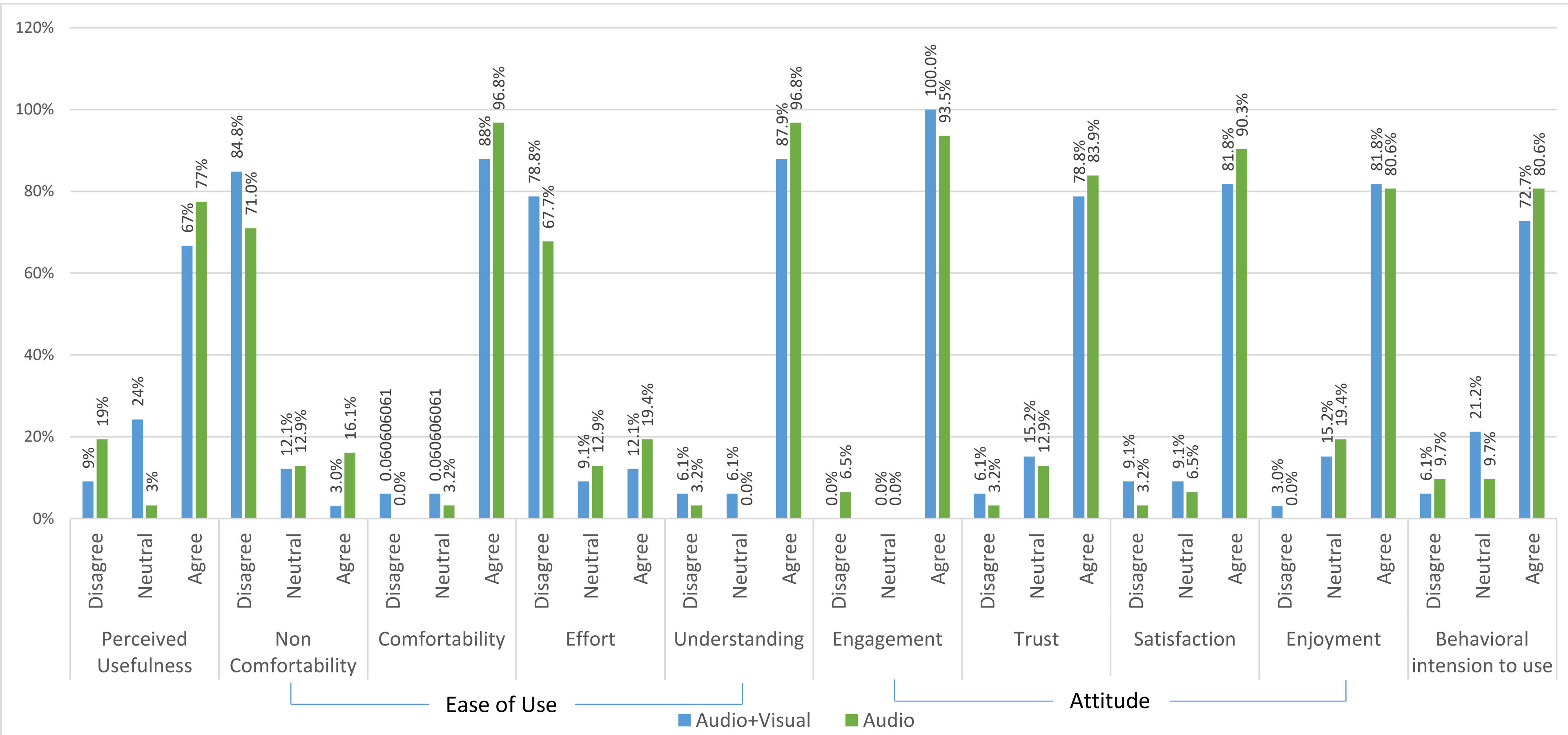
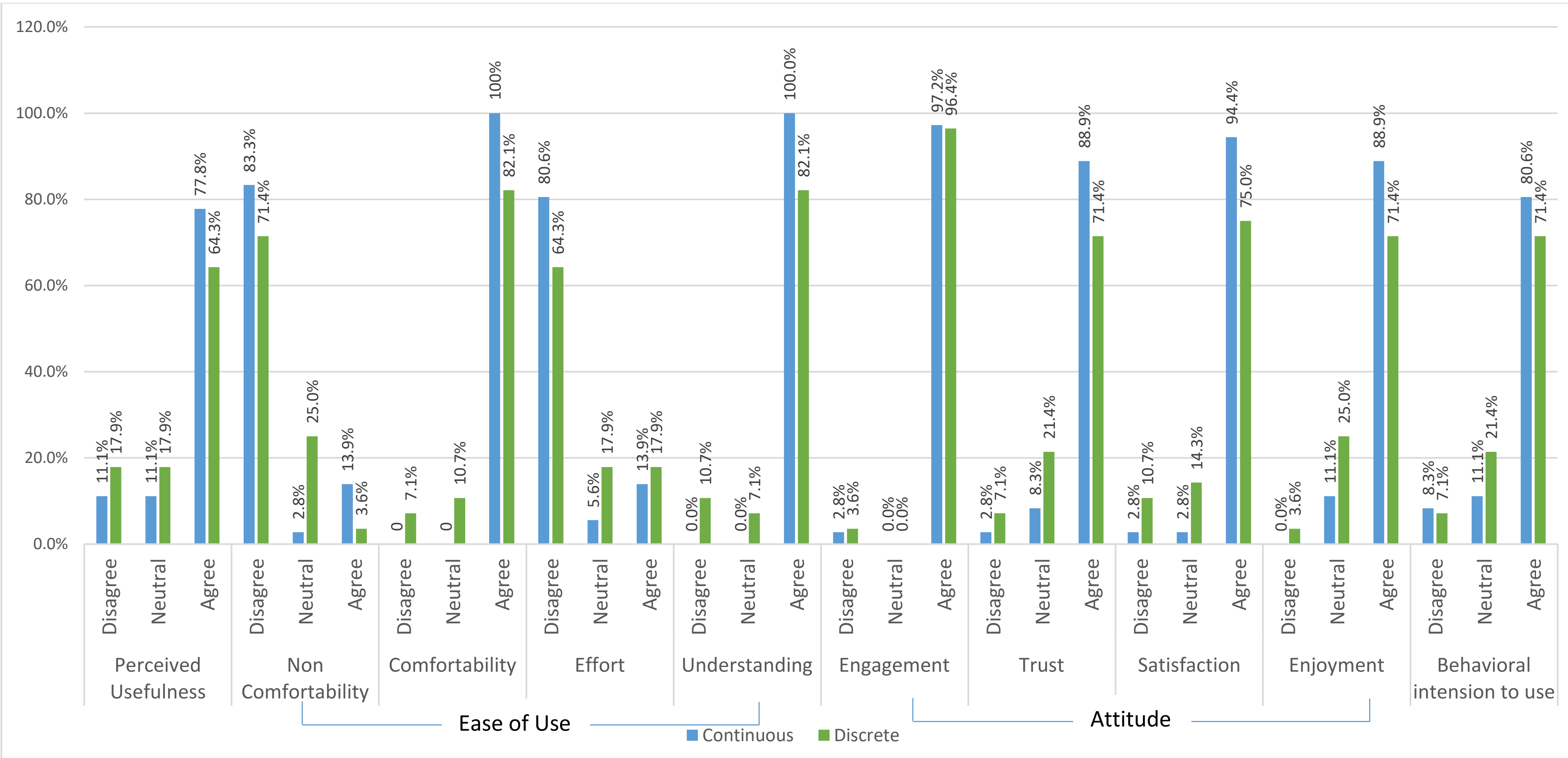
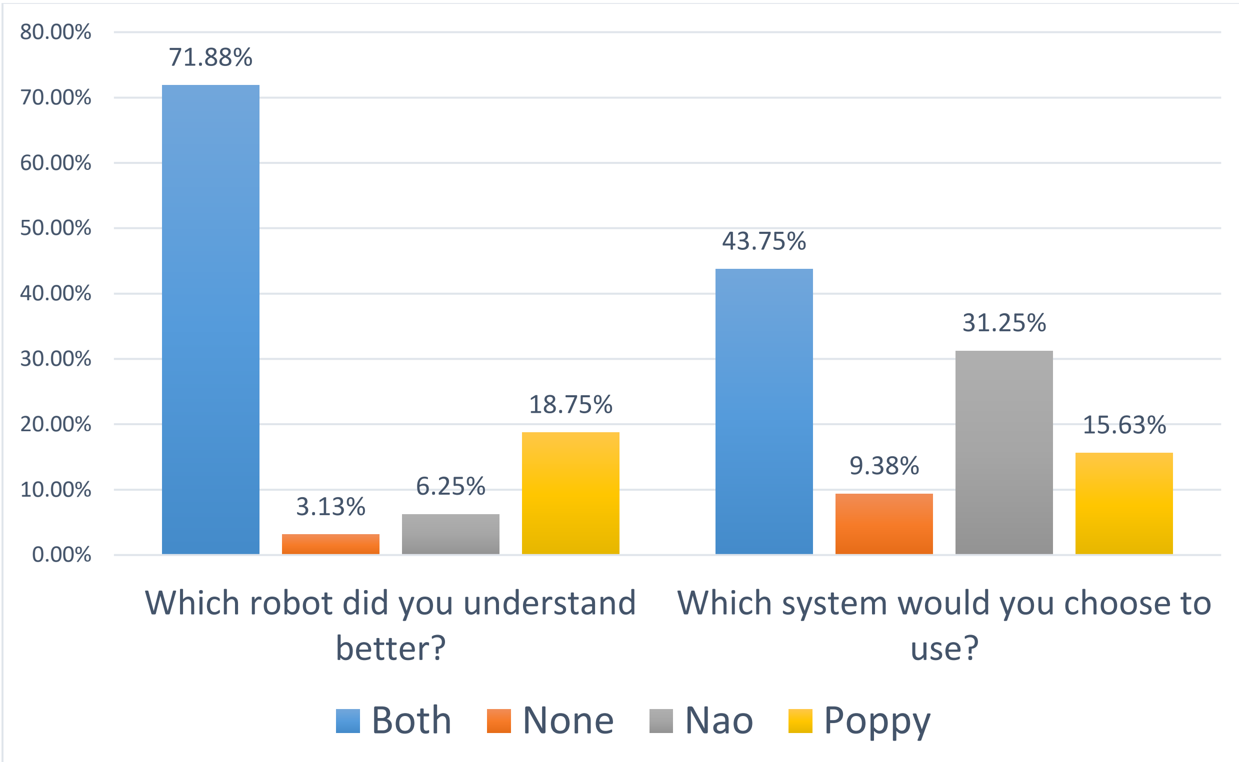
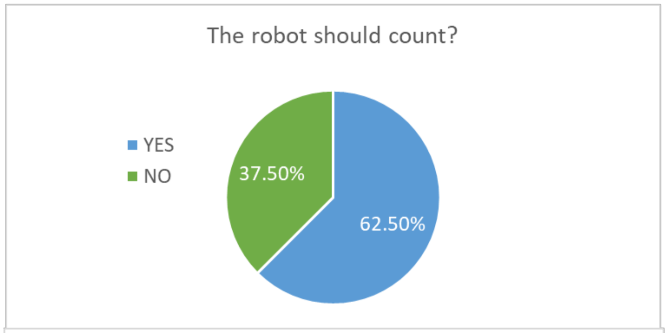


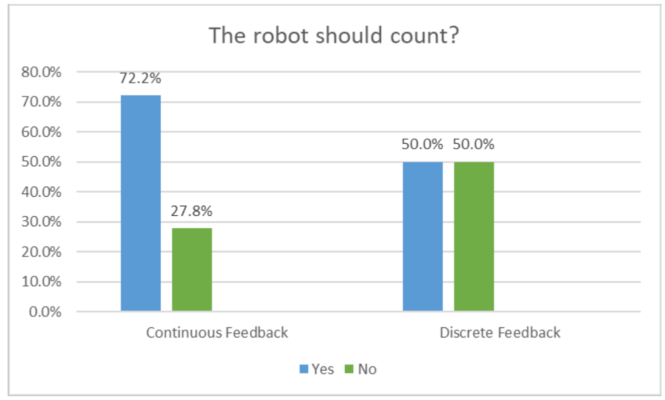
Table 21: Subjective evaluation of the training - timing of feedback

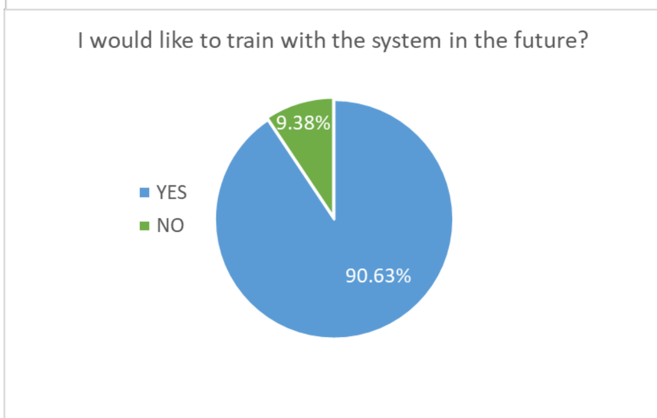


7.2.7 Appendix P – Final questionnaires analysis




The robot should count?
YES
NO
37.50%
62.50%


The robot should count?
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
72.2%
27.8%
50.0%
50.0%
Continuous Feedback
Discrete Feedback
Yes
No


I would like to train with the system in the future?
YES
NO
9.38%
90.63%

תקציר

אוכלוסיית הקשישים בעולם גדלה במהירות וכך גם תוחלת החיים. רוב המבוגרים מעדיפים לשמור על חיים עצמאיים. הוכח כי פעילות גופנית תורמת לאיכות החיים ומציעה יתרונות בריאותיים שונים. היא חשובה לשמירת המצב הקוגניטיבי, הנפשי והגופני עבור מבוגרים. בנוסף, היא מעכבת ירידה בתיפקוד וממזערת את שיעור הדיכאון, המוגבלויות והתמותה.

במחקר זה, פותחה מערכת רובוטית אשר תשמש כמאמן אישי למבוגרים. מטרת המערכת הינה לעודד את המבוגרים לבצע יותר פעילות גופנית. הרובוט מנחה את המשתתפים ומדגים תרגילי ספורט שונים. המערכת מעניקה משוב חיובי ומתקן בזמן אמת על- פי ביצועי המשתתפים כפי שזוהו על ידי מצלמת ה-Kinect. במסגרת המחקר פותחו שתי מערכות רובוטיות בשפת Python.

בוצעו ניסויים מדעיים המורכבים משני רובוטים דמוי אדם, Nao and Poppy, אשר נועדו לקבוע את התזמון הטוב ביותר ואת אופן מתן המשוב אשר יתאימו להעדפות המשתמשים, יעודדו אותם לביצוע פעילות וישפרו את האינטראקציה שלהם עם המערכת. בנוסף, בוצע מחקר השוואתי בין שני סוגי הרובוטים על מנת לחקור עם איזה רובוט שביעות הרצון גבוהה יותר באימון.

עשרה מבוגרים, בגילאי 67-85, השתתפו בניסוי הראשוני שנערך בסביבה ביתית בכדי לשמור על אינטראקציה טבעית ככל האפשר. נעשה שימוש בסימולטור של הרובוט Nao עקב תקלה ברובוט האמיתי ונמצא כי % 70 מהמשתתפים הביעו את כוונתם להשתמש במערכת בעתיד.

בהמשך לניסוי הראשוני, נעשה מחקר המשר אשר כלל 32 מבוגרים בגילאי 70-88. הניסוי היה בין-תוך נבדקי והמשתנים הבלתי תלויים היו תזמון המשוב, אופן המשוב וסוג הרובוט. כל מבוגר קיים אינטראקציה עם כל אחד מהרובוטים בסדר אקראי והעדפות המשוב נבדקו. המשתנים התלויים היו: שימושיות המערכת, קלות השימוש בה, גישת המשתמשים אל המערכת ורצונם להשתמש בה. המשתנים הוערכו באופן אובייקטיבי וסובייקטיבי. המחקר מראה את הפוטנציאל של מערכת רובוטית לאימון של אנשים מבוגרים. המערכת מעודדת את המבוגרים להתאמן יותר בפעילות גופנית אשר מועילה לבריאות ורווחת המבוגרים. בנוסף, המחקר מספק הנחיות עיצוב למערכת כזו.

התוצאות הראו כי המערכת ממלאת את המטרה לעודד מבוגרים להתאמן. מרבית המשתמשים חשבו כי המערכת שימושית וקלה לשימוש, היו בעלי גישה חיובית אל המערכת ורצו להשתמש בה. עוד הראו התוצאות כי הרובוט Poppy עורר עניין רב יותר בקרב המשתמשים מאשר הרובוט Nao. בנוסף,משתמשים אשר התנסו במשוב ויזואלי וקולי התלהבו יותר מהמערכת ודיווחו כי הייתה קלה יותר לשימוש בהשוואה למשתמשים שהתנסו במשוב קולי בלבד.

מילות מפתח: מבוגרים, פעילות גופנית, משוב, רובוט דמוי אדם, Kinect, NAO, Poppy.

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חתימת המחבר........................ תאריך...11/12/2019...

אישור המנחה/ים..................... תאריך...11/12/2019...

אישור יו״ר ועדת תואר שני מחלקתית.... .... תאריך..................... 18/12/19

כסלו תשע״ט דצמבר 2019

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כסלו תשע״ט　　　　דצמבר 2019